CHANGING ROLE OF HILL FARMING IN SCOTLAND

(Volume 2)

APPENDICES

Claire R.C. Morgan-Davies

A thesis submitted for the degree of

Doctor of Philosophy

College of Science and Engineering
The University of Edinburgh

November 2013

Table of Contents

APPENDIX I.

Methodologies Review

I.I. Examples of Scottish Government consultations affecting hill land in Scotland

(from 2003 – Scottish Government, 2012)

Year	Consultations
2003	• Consultation on Land Reform (Scotland) Act 2003 Part 3: Crofting Community Right to Buy • CAP Reform: Opportunities for Scotland • Land Reform (Scotland) Act 2003 - Part 2: Community right to buy: Consultation on draft regulations • Towards a strategy for Scotland's Biodiversity: Biodiversity Matters! - A draft for consultation • Nature Conservation (Scotland) Bill. Part 1 - A draft for consultation • Proposals for Changes to Agri-Environment Schemes in Scotland • Part 2 - CAP Reform: Consultation on Mid Term Review of Agenda 2000
2004	• CAP Reform: Cross Compliance (Good Agricultural and Environmental Condition) • Part 1 Land Reform (Scotland) Act 2003 - Draft Guidance for Local Authorities and National Park Authorities • CAP Reform: Land Management Contracts Menu Scheme • Consultation on Draft Rural Development Regulation
2005	• The National Forest Land Scheme; land for communities and affordable housing • Draft Crofting Reform (Scotland) Bill Consultation Paper • Introduction of the new Environmental Impact Assessment (Scotland) Regulations
2006	• Rural Development Programme for Scotland 2007-2013 - The Strategic Plan • Scottish Executive Rural Group: Paper 2006/2 - Enhancing Our Care of Scotland's Landscapes • Scottish Forestry Strategy Review • The Conservation (Natural Habitats, &c.) Amendment (Scotland) Regulations 2006 • Consultation on the Rural Development Programme for Scotland 2007 - 2013
2007	• Scottish Executive Consultation: Future European Structural Funds Programmes in Lowlands & Uplands Scotland 2007 - 2013 • Scotland's first coastal and marine national park: A consultation • Wildlife and Countryside Act 1981 Schedule 4 Species Review - Public Consultation

Continued

Year	Consultations
2008	• Crofters (Scotland) Act 1993 and Crofting Reform etc. Act 2007: Consultation on Designation of New Areas for Crofting • Climate Change: Consultation on Proposals for a Scottish Climate Change Bill • Future Implementation of the Common Agricultural Policy in Scotland: A Consultation Paper • Consultation on Less Favoured Area Support Scheme in Scotland (2010-2013)
2009	• Consultation on the finding of the National Parks Review • Scottish Climate Change Bill - Forestry provisions • Draft Crofting Reform (Scotland) Bill Consultation Paper • Implementation of the Common Agricultural Policy (CAP) Health Check in Scotland: a consultation paper • Wildlife and Natural Environment Bill - Consultation Document
2010	• Proposal to Modify the Cairngorms National Park Designation, Transitional and Consequential Provisions (Scotland) Order 2003 • Proposal to Modify the Loch Lomond and the Trossachs National Park Designation, Transitional and Consequential Provisions (Scotland) Order 2002 • Inquiry into the Future of Support for Agriculture in Scotland • Land Registration (Scotland) Bill Consultation • Getting the best from our land: A draft land use strategy for Scotland: Consultation for discussion and feedback
Current	• Consultation on the European Commission's proposals for the future Common Agricultural Policy

I.2. Summary of multi-variate analysis techniques for typology studies

Multivariate analysis method	Studies	Sample size	Reference
PCA	Livestock management and economic indicators in Spanish dehesas	46 farms	Gaspar et al., 2008
	Dairy goat grazing systems in Mediterranean regions	45 farms	Ruiz et al., 2009
	Evaluation of the effects of adopting a new feeding technology in Mediterranean sheep farming systems	79 farms	Olaizola et al., 2008
	Pattern of utilisation of grazing resources by sheep in Spain	53 farms	Riedel et al., 2007
	Economic profitability of sheep farms in Spain	52 farms	Milán et al., 2003
	Management strategies and land use for Roquefort cheese production (sheep farms in France)	32 farms	Quetier et al., 2005
	Categorising goat systems in Spain	61 farms	Gaspar et al., 2011
	Sustainability of Spanish extensive farms	69 farms	Gaspar et al., 2007
Common Factor Analysis (on categorical variables) & PCA	Silvo-pastoral practices in France	150 farms	Rapey et al., 2001
Multiple correspondence analysis/ Correspondence factor analysis (Multiple Correspondence Analysis=counterpart of PCA for categorical data)	Characterisation of dehesas beef cattle farms	130 farms	Milán et al., 2006
	Categorisation of farming practices in mountain areas in France	33 farms	Girard et al., 2008
	Role of grazing livestock systems for rangeland conservation	62 farms	Bernués et al., 2005
	Characterisation of semi-extensive goat production systems in Spain	89 farms	Castel et al., 2003
	Study of the Territorial Exploitation Contract in France	66 farms	Gafsi et al., 2006

APPENDIX II

Pre-survey and survey results for building the Adaptive Conjoint Analysis

II.1. Results of the pre-survey: List of characteristics defining a hill system

Characteristics mentioned by respondents	number of times mentioned	Broad attributes (defined by researcher)
soil type	9	Physical environment
weather	8	
temperature	5	
slope	5	
wind	3	
access	3	
harshness	1	
environmentally fragile	3	
heather	9	Upland vegetation
bracken	2	
lichens	2	
gorse	1	
alpine plants	2	
bog myrtle	1	
wetland	1	
rushes	2	
moss	2	
others	4	
unimproved grassland	6	
forestry	18	Woodland
inbyes	3	Improved pastures
shelter belts	1	
wildlife	9	Wild mammals
upland birds	16	Upland birds
livestock	22	Livestock & Farming products
invertebrates	6	Invertebrates
butterflies	3	
livestock management	7	Livestock management

Continued

Characteristics mentioned by respondents	number of times mentioned	Broad attributes (defined by researcher)
recreation	17	Access & Recreation
access	4	
farms	8	Farms
architecture/archeology	6	Architecture/archeology
rurality	10	Rurality
tourism	2	Tourism
estates	1	Socio-economic elements
no cropping	2	
economically fragile	2	
socially fragile	2	
housing	1	
environmental payments	1	
local economy	1	
labour	3	Jobs and local employment
open spaces	2	Topography/Landscape
big skies	1	
water	8	
moutains, hills & glens	4	
scree & rocks	1	
rocky outcrops	1	
shape of hills	1	
ondulating countryside	1	
grouse moors	1	Game management
common management	2	Land Use
what it support	1	

II.2. Survey sent to rank the 20 attributes and define the best 5

Dear Sir/Madam,

My name is Claire Morgan-Davies and I am a researcher at the Scottish Agricultural College. We are currently undertaking a project to identify the characteristics needed to design practical land management systems that would combine farming requirements and animal welfare, social value and environmental benefits within the hills and uplands of Scotland.

As part of this project, we are carrying out a short survey, to better understand how land managers and others people with a primary interest in conservation or in rural communities define upland land management systems.

The background of this research is that given CAP reform, the new agri-environmental schemes and changes in the rural society, the management of our hill lands is getting more complex. Land managers and policy makers are constantly asking 'What do we want our hill land to deliver?'. To try to answer this question, we need **your** views on what defines a hill system. By giving us **your** idea of definitions and characteristics of a hill system, we will then be able to use this information to design a computer-based questionnaire. It will allow us to quantify trade-offs and choices of different outcomes for the hills and uplands, as defined by those directly involved on the ground, *i.e.*, yourself and others contacted in this survey. Ideally, this would give us a range of 'optimum' management systems that would satisfy farmers, conservationists, rural communities and the welfare of the livestock in our care.

We wish to focus on hill or moorland, with unimproved or semi-natural vegetation (the type and quality of habitat being one of the answers we are seeking from you). Such land needs to have the capacity for livestock grazing (with different levels of care), with wildlife present and hill walking, as well as providing other access opportunities.. It is **your** definition of what is important and what characterises these systems that we are seeking from you.

We obtained your details either from the relevant Internet websites, our SAC offices or SAC contacts, and have designed this survey after consulting with a range of researchers, agricultural advisers and practitioners. Please respond as an individual, not as an official response of any body to which you are linked (all responses will be treated anonymously).

Your help is essential to the study's success and we greatly appreciate your involvement.
Once you have completed this survey, please send it back to myself either by email or by using the stamped envelope enclosed.

If you have any questions, please do not hesitate to contact me by phone on 01838 400210, or by mail or email.

Yours sincerely,

Claire Morgan-Davies
Livestock Systems research scientist
SLS, SAC Kirkton,
Crianlarich, FK20 8RU
Tel: 01838 400210, Fax: 01838 400248
Email: claire.morgan-davies@sac.ac.uk

1. **In which professional category would you place yourself? (Please tick one box)**

Commercial estate manager	☐	Veterinarian	☐
Conservation land manager	☐	Community agent	☐
Researcher	☐	Farmer	☐
Agricultural adviser/consultant	☐	Other (please specify)	☐
Policy adviser	☐	…………………………………	

2. **What are your main professional interests? (Please tick one -or several, if appropriate - box (es))**

Livestock production ☐

If you have moorland or hill farming interests, tick your main production outputs:

Specialist Sheep	☐
Specialist Beef	☐
Cattle & Sheep	☐
Mixed	☐

Forestry/Woodlands ☐

Nature conservation ☐

Please specify, if possible:

Birds	☐
Plants	☐
Woodlands	☐
Mammals	☐
Invertebrates	☐
Local nature conservation	☐

Animal care and welfare ☐

Rural communities ☐

Please specify, if possible:

Farming	☐
Conservation management	☐
Public access and enjoyment	☐
Business viability	☐
Local employment & economic activity	☐

3. In a previous survey amongst other researchers and advisers, a list of characteristics (with some keyword they mentioned) was drawn up. From this list (below), tick 5 characteristics that, in your opinion, best describe and define a hill land system. Then rank their importance for you, where 1 is most important and 5 is the least important. You can add more characteristics in the blank spaces if you feel they are more appropriate.

Characteristics	**Tick**	**Rank**
Access and other recreation opportunities		
Archaeology & Architecture		
Improved pastures		
Farming products (lambs, breeding livestock, cattle, wool)		
Game management (deer and grouse)		
Presence of farms (sheds, quad bike tracks, deer fences, stone fanks)		
Invertebrates		
Jobs and local employment		
Landscape (lochs, streams, mountains, glens, moors) & Topography (open spaces, shape of hills, slope)		
Land use management		
Livestock (sheep, cattle, alternative livestock)		
Livestock management (wintering & feeding regime, stocking density, grazing, infrequent attention from farmers & vets)		
Physical environment (soil, climate, slope, accessibility, fragility)		
Rurality and remoteness (narrow roads, small villages, few vehicles)		
Socio-economic elements (big estates, housing, local economy, labour supply)		
Tourism		
Upland birds		
Upland vegetation		
Wild mammals (deer, badgers, foxes, voles, feral goats)		
Woodland		

4. Having picked and ranked the characteristics that you consider important in Q3, identify what level (*e.g.* quantity (and names) of species, x numbers of rural activities, quality of farming outputs, type of management or any other specific description) of each would make both a) a GOOD hill land system and b) a POOR hill land system

EXAMPLE: for an arable environment

Characteristics from Q3		
Farming products	*Good system*	Good yield of quality cereals sold at good price, to a premium buyer (malting) Good quality straw for feeding
	Poor system	Low yields of feeding cereals, with low dry matters and pest damage. Straw too poor to bale.
Hedges and trees	*Good system*	Good quality hedges, managed under best practice for biodiversity with some excellent specimen trees and young replacement trees now developing
	Poor system	No or sparse hedge, with specimen trees not being managed and derelict and with no new hedgerows or individual trees planned.
1.	*Good system*	
	Poor system	
2.	*Good system*	
	Poor system	
3.	*Good system*	
	Poor system	
4.	*Good system*	
	Poor system	
5.	*Good system*	
	Poor system	

Your answers will be compiled using statistical methods, to identify which characteristics and which levels are most important. This will help us prepare the next phase of this research. A computer-based questionnaire will be designed using the information you have supplied, to finalise this part of the project.

Would you be willing to complete a follow-up questionnaire?

YES ☐ NO ☐ (please tick)

If yes, what method would be easiest for you? (Please tick one box)

Computer based (floppy disk sent to you) ☐

Interview with the researcher (recorded on laptop) ☐

Would you like us to send you the results of this part of the project?

YES ☐ NO ☐ (please tick)

NOTE: The above two questions require that we know who you are, but please note that in all other respects, your answers to the other questions will be treated anonymously and not linked to your name or with the body which you are associated. This part of the form will be kept separate from the other questions. Providing your name will assist in identifying response rates.

Name:

Thank you very much for your assistance.

APPENDIX III

Examples of layout of the Adaptive Conjoint Analysis

III.1. Introduction

We want your views of the future contribution of different characteristics towards the economic, environmental and social sustainability of hill land areas in Scotland We have asked many people to characterise a hill system and this questionnaire is based on their answers.

Hill lands are complex ecosystems, and at the site level, this often means making *trade offs* of one characteristic versus another for appropriate management, within the unalterable constraints of the landscape and physical environment.

Given the complexity of the social, environmental and economic issues, and the enormous influence of ever changing policies, we want you to provide a 10 year vision as to how we manage our hills NOW.

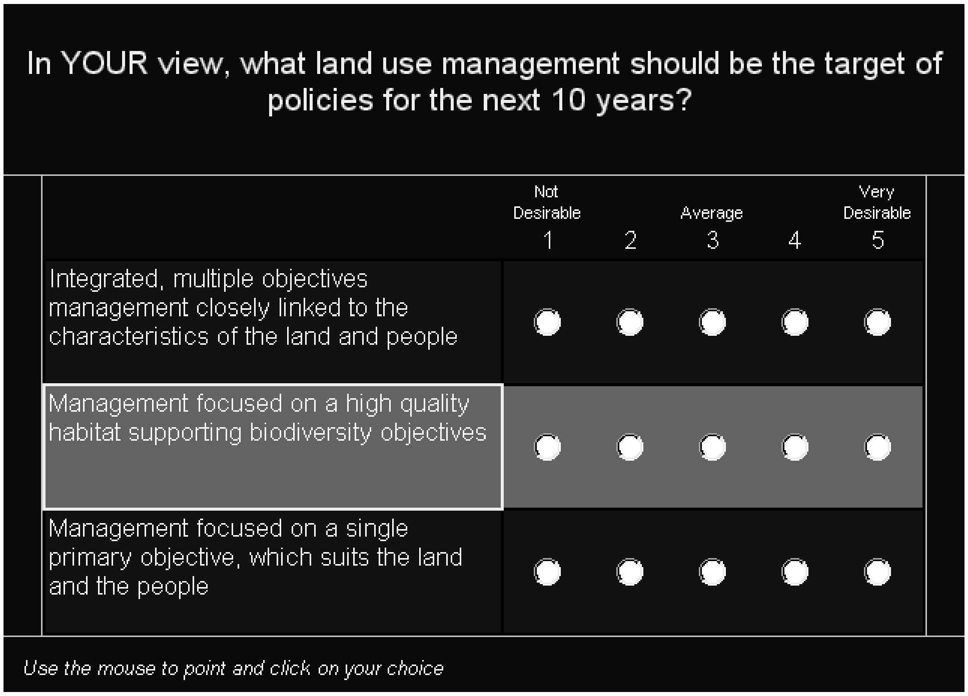
The context for the following questions is a generalised view of areas of hill, mountain and moorland in Scotland, together with the peripheral areas they directly connect with, rather than a wider view of 'the Highlands'.

It is the **management** of (and the policy influences upon) the considerable areas of this wild, semi-natural country, albeit connected to land further down the hill, that is the focus for this questionnaire.

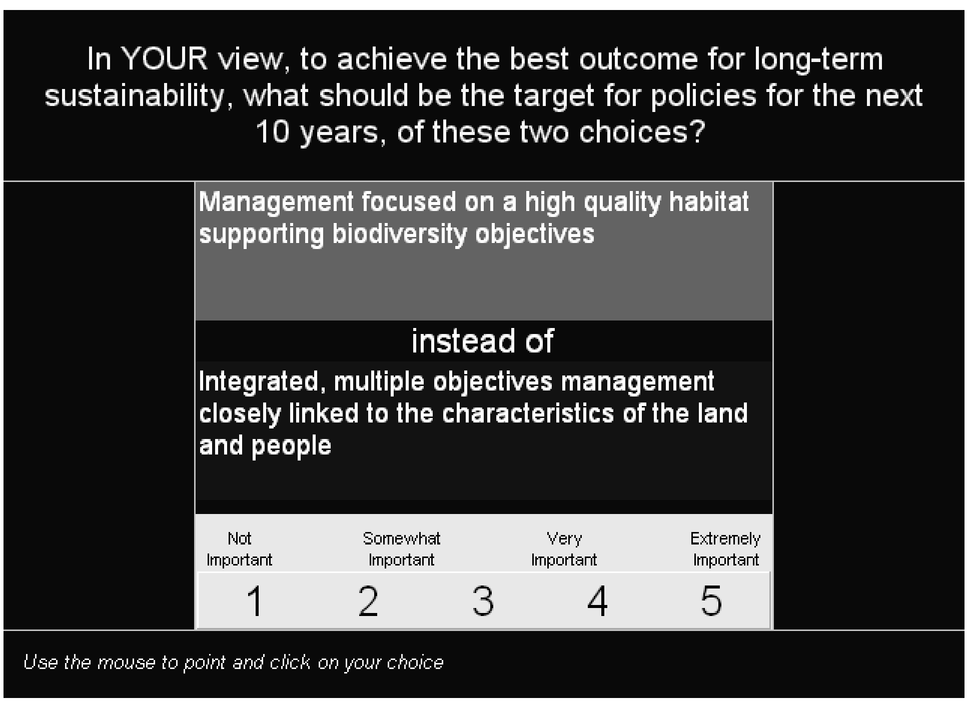
Please be patient with the questions, there are no 'right' or 'wrong' answers. The choices get ever more complex and some of the combinations may seem unacceptable. Use the "Help" button for more details on some of the characteristics at the start. Use "Previous" to go back.

Thank you!

III.2. Example of the rating questions (5 questions in total)

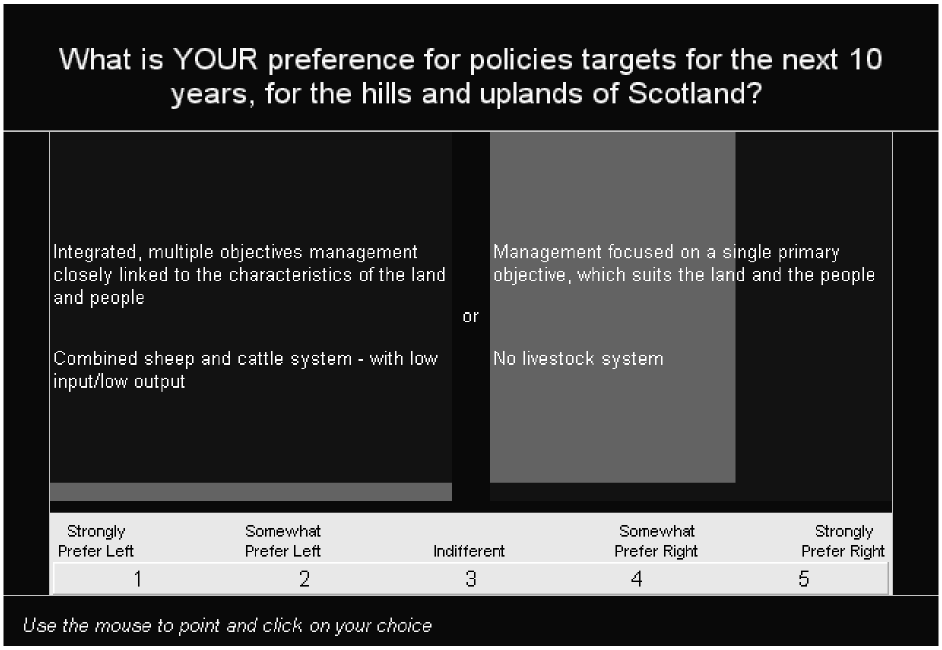


III.3. Example of the importance questions (5 questions in total)



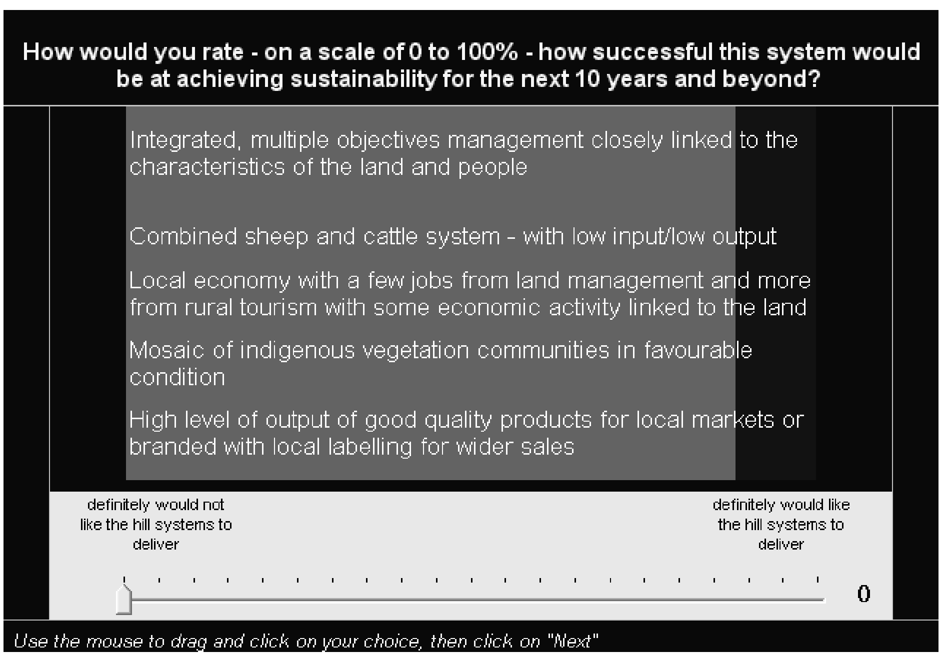
III.4. Example of the paired questions (24 in total, with 9 prohibited pairs)

2x2 paired questions

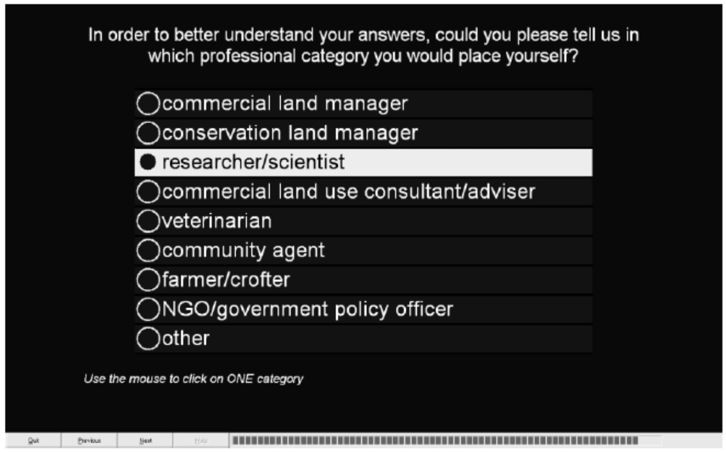


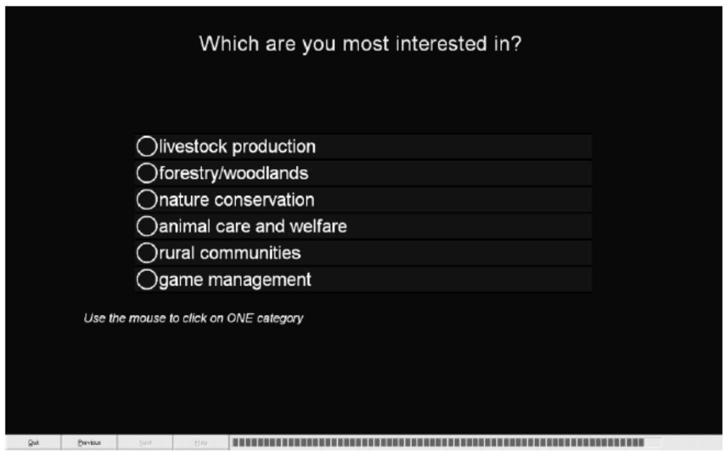
The ACA software also proposed 3x3 and 4x4 paired questions.

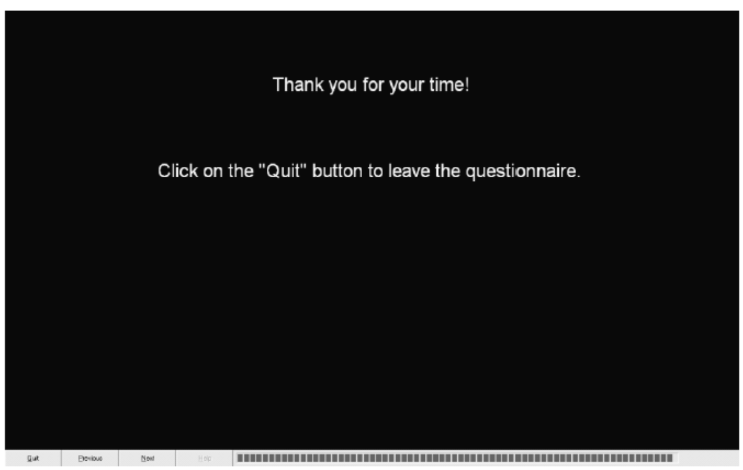
III.5. Example of the calibration questions (5 in total)



Final questions:







APPENDIX IV

Hill Farmers' Survey and Interviews

IV.1. Template for the postal survey

POSTAL SURVEY
Management Practices, Change by Farmers in response to CAP reform, and future plans

Part A. Background Questions

Name of the farm (or Post Code)	**A.1.** What is the size of your farm (how much do you farm)? ....(ha)
A.2. In 2006, what were your areas of: ha • Inbye ...... • Hill ground .... • Cereals .... • Fodder crops .... • Hay/silage .... • Other	ha Conifer woodland • Of which you manage commercially .... • Of which you manage non-commercially .... • Of which you do not manage at all .... Broadleaved woodland • Of which you manage commercially .... • Of which you manage non-commercially .... • Of which you do not manage at all ....
A.3. Which of the following best describes your tenure? (tick more than one box if need be)	☐ Tenant ☐ Owner-occupier ☐ Mixed ☐ Seasonal lets only ☐ Contract farmer ☐ Other..........................
A.4. Are you mainly; ☐ LFA specialist sheep farm ☐ LFA specialist beef farm ☐ LFA sheep & beef farm ☐ Other (please specify):.. Are you a; ☐ Sole trader ☐ In partnership ☐ Company	**A.5.** Numbers of animals in 2006 How many breeding ewes did you have? ....(No.) ....(Breed) .... How many lambs did you wean (roughly)? .... How many cattle (and of what type and breed)? ....(Type) ....(No.) .... (Breed) .... What bull do you use? ....
A.6. What do you think is the maximum number of ewes (of your current types) your farm could carry (compared to now)?... If you don't carry this number, why not? (circle & rank) Welfare, labour, infrastructure, weather, performance, economics, forage availability, others	

1

A.7. What do you think is the maximum number of cattle (of your current types) your farm could carry (compared to now)?..

If you don't carry this number, why not? (circle & rank)
Welfare, labour, infrastructure, weather, performance, economics, forage availability, others

A.8. How have you come to the number of stock you carry on the farm?
(explain both history and current stocking)
Why?

A.9. Labour – Family labour How many hours (or % of time) do you spend on:	Farmer	Partner (wife/husband)	Business partner (son/father/other)
Working on farm Working off-farm (farming activity) Working off-farm (non-farming)			

Employee/Contractors

- Number of full-time employees ....
- Number of part-time employees? ....
- How many contract workers for how many days? ....
(e.g. 2 contractors approx 60 days per year in total)
- What work do the contractors do? ....

A.10. What are your outputs? (tick more than one box if need be);	%	Where do you sell them? (precise market/abattoir/direct sales)
☐ Hill store lambs	......	....
☐ Cross-bred store lambs	....	....
☐ Finished lambs	....	....
☐ Ewe lambs for breeding	....	....
☐ Tups for breeding	....	....
☐ Draft ewes/pedigree ewes	....	....
☐ Store cattle	....	....
☐ Finished cattle	....	....
☐ Other (please specify)	....	....
....		

A.11. Are you part of a co-operative group to sell your animals?	Yes/No Which ones?
A.12. Did you produce your own hay or use a contractor in 2006? Did you produce your own silage or use a contractor in 2006?	☐ Self ☐ Contractor ☐ No silage/hay

2

A.13. Do you have seasonal grazing?	☐ Self ☐ Contractor ☐ No silage/hay Yes/No

A.14. Other farm activities:

A.14.1. Which of the following activity do you have on the farm?
- Farm shop
- Tourist accommodation (please specify, with places/beds) ....
- Forestry
- Sporting (please specify)
- Phone Mast
- Energy production (eg, hydro-electric, wind)
- Others (detail)

A.14.2. When did you start these other farm activities?

A.14.3. Did you change anything regarding these activities in the past 2 years?
Why?

A.14.4. Please rank in order of importance of income your farm activities
(ie, are you more interested in your forestry than livestock, or do you devote more time on your tourist activity than on your farming activity, etc.?)

A.14.5. How much of your household income comes from farming? (in %)

A.15. What is your personal motivation for carrying on farming/land management in the future? (tick **one** only)

☐ Profitability until you retire
☐ Providing a working system for the next generation
☐ Developing an environmentally friendly system, even though not always profitable
☐ Enjoy farming/land management and will carry on regardless
☐ Other (please specify)...

A.16. Which age-bracket are you in?

☐ 18-30 ☐ 31-45 ☐ 46-60 ☐ Over 60

A.17. What level of education do you have?

o School leaver o Secondary o Higher qualification o University

A.18. How many years have you lived in the area?

Part B. CAP Reform questions (please use additional sheet if necessary)

Question	Answer	What	Why?
B.1. Have you made any changes to your management of livestock since 2001?	☐ Yes ☐ No		
B.2. Have you made any changes to your choice of crops since 2001?	☐ Yes ☐ No		
B.3. Have you made any changes to your management since May 2005 as a consequence of CAP Reform, or are you planning to do so within the next 12 months?	☐ Yes ☐ No		
B.4. Are you planning any management changes in the long term, ie within the next 5 years?	☐ Yes ☐ No		
B.5. What options might other farmers in the area consider, as a result of CAP reform?			

Thank you for your time!

IV.2. Template for the Interviews (with the help of a map)

Farm no. Date:

Part A. The actual system

1. Management of animals during the year:	
1.1.Where do you tup the ewes? *(mark on map areas)* 1.2. What is your main cow calving season (if approp) 1.3. Where do you mate the cows?	Hill / hill park/ field/ shed/ others ………………………………………… Hill / hill park/ field/ shed/ others
1.4. Where are your breeding ewes throughout the winter – tupping to lambing? 1.5. Do you feed them during winter? 1.6. What do you feed them? 1.7. How often?	Hill / hill park/ field/ shed/ others Yes/No ☐ Block ☐ Hay or silage? ☐ Concentrates – how? ☐ Daily ☐ Weekly ☐ Other (precise)
1.8. Where do the cows/cattle spend the 1st part of winter (Oct till February) 1.9. Where do you feed them? 1.10. What do you feed them? 1.11. How often?	Hill / hill park/ field/ shed/ others Hill / hill park/ field/ shed/ others ☐ Block ☐ Hay or silage? ☐ Concentrates - how ☐ Daily ☐ Weekly ☐ Other (precise)
1.12. Do you pregnancy scan? 1.13. If Yes, do you separate the animals according to scanning results?	☐ Yes ☐ No ☐ Yes ☐ No
1.14. Where do you put the twins/ewes/animals at risk?	Hill / hill park/ field/ shed/ others
1.15. When do you start lambing?	
1.16. Where do you lamb your • Single shed/inbye field/hill park/hill • Twins shed/inbye field/hill park/hill • Gimmers shed/inbye field/hill park/hill	Location: ………………………… …………………………
1.17. Where do you calve?	Hill / hill park/ field/ shed/ others

1.18. Where do you summer graze your ewes/lambs? 1.19. Where do you summer graze your cows/cattle?	Hill / hill park/ field/ shed/ others Hill / hill park/ field/ shed/ others
1.20. Where do you fatten your : Lambs: shed/inbye field/others (details) Cattle: shed/inbye field/others (details)	

2. Management

2.1. Have you got a closed flock? Yes/No
2.2. Do you buy new stock? Yes/No
2.3. If yes, is there a disease risk? Yes/No/Why?

2.4. Did you ever brought in any diseases in the past? Yes/No/ Details

How?

2.5. Describe different sections of your farm in terms of quality and quantity of grazing available to sheep; (based on farm map/sketch)

	Quality of grazing for sheep	Quantity of grazing for sheep	Are there months when quality or quantity can go either way (i.e there are risks of either under- or over-) (which?)
Hill	Good/average/poor	sparse/sufficient/abundant	
Parks/Intake	Good/average/poor	sparse/sufficient/abundant	
Fields/ Improved grass	Good/average/poor	sparse/sufficient/abundant	
Fields for hay/silage/ aftermaths	Good/average/poor	sparse/sufficient/abundant	

2.6. Do you have deer that come on your land?
Yes/No
2.7. If yes, how many?(please circle) less than 10/between 10 & 50/more than 50

2.8. Do you have a culling plan?
Yes/No

2.9. What is your culling percentage?.........................

2.10. Do you feed the deer?
Yes/No

2.11. Do you have a Deer Management Plan?
Yes/No

2.12. Where do you get casual and contractor help from?
<5 miles / 5-20 miles / 20-50 miles / >50 miles

2.13. Which supplies do you get?

	Name of suppliers	Location
Straw/bedding	....	....
Hay	....	....
Silage	....	....
Supplement feeds	....	....
Fertilisers	....	....
Vet supplies	....	....
Others?	....	....

Distances		
2.14. For gathering, typically how long does it take?	☐ Longest gather: ☐ Shortest gather:	....
2.15. How many gathers are there on your farm?	....	....
2.16. How many people are needed for the biggest and smallest gather?	biggest: smallest:	....
2.17. How long does it take to feed your animals during winter?	☐ Longest ☐ Shortest	
2.18. How is this travel?	On foot/on a bike/on the hill/on public roads	
2.19. Are distances an issue? Yes/No Why?		

2.20. Do you have an 'official'animal health strategy?
Yes/No
Which Plan is it?

2.21. Is you strategy
prevention (pro-active)
reaction

Could you please list:
2.22. Use of veterinarians (Yes/No/How often)........................
2.23. What are the most common diseases among farms in this neighbourhood?

2.24. What do you think is your biggest problem of disease on your farm?

2.25. What do you do about it?

Schemes:
2.27. Which of the following schemes are you currently involved in? (circle)
Rural Stewardship Scheme (RSS), Environmentally Sensitive Area (ESA), Countryside Premium Scheme (CPS)
Woodland Grant Scheme (WGS), Land Management Contract Menu Scheme, ,
Scottish Forestry Grant Scheme (SFGS), , Organic Aid Scheme (OAS)
Others (..............................)

3. Resources, risk, decision taking

3.1. Would you consider using your resources (capital/buildings/labour/machinery) for something else than farming?
Yes/No/Why?

3.2. If you were to increase your numbers of animals (sheep/cattle), would
your buildings be fit for purpose? Yes/No Why?

your machinery be fit for purpose? Yes/No/Why?

you have enough labour to cope with the increase of farming? Yes/No/Why?

3.3. If you did not plan to change anything to your actual farming activity, are your buildings fit for purpose?
Yes/No/Why?

3.4. If you planned to decrease your farming activity (having less animals), would
your buildings be fit for another use? Yes/No/Which one?

you be prepared to do something else? Yes/No/Why?

3.5. Would you be prepared to borrow money to begin a new venture? Yes/No/ Why?

Attitude to risk
3.6. For example, if you saw a tup/bull that you liked the look of it, but of unknown background or if you did not know the seller at the market, would you buy the animal? Yes/No/Why?

3.7. On your farm, would you say that you (tick)
- ☐ Are adverse to taking risk
- ☐ Like to know the odds before making any decisions
- ☐ Are a bit of a gambler

3.8. How often does your system fail?
Never/seldom/sometimes/often

3.9. Do you have a successor? Yes/No
Why?

3.10. What do you think will happen to the farm after you 'pass it on'?

3.11. What is the history of your farm? (has it been in the family for long, etc...?)

How do you agree or disagree with the following statements

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I aim produce the best quality output on my farm	o	o	o	o	o
I will try to diversify my income	o	o	o	o	o
I intend to carry on farming regardless	o	o	o	o	o
Profit making is my main motivation in farming	o	o	o	o	o
I will farm for the next generation to take over	o	o	o	o	o
I will try to be more efficient/cost effective	o	o	o	o	o
I will try to improve/maintain/care for the environment	o	o	o	o	o
I want to farm with less government subsidies	o	o	o	o	o
I want to farm with less outside interference (laws, codes, NPA, landlords, etc.)	o	o	o	o	o
I would like to have more quality time for things other than farming	o	o	o	o	o
	o	o	o	o	o

Part B. Changes following CAP reform and changes of rules

B.1. Changes since 2001:

B.1.1. Have you made any changes to your numbers and management of livestock between 2001 & 2005?
Yes/No/NA
B.1.2. What

B.1.3. Why?

B.1.4. Who made the decision?

B.1.5. What was it based on?
Financial/Personal/Others

Do you think it will have an impact on:
B.1.6. Paid labour (increase/decrease/no change)
B.1.7. Unpaid labour (increase/decrease/no change)
B.1.8. Habitat (improve/damage/no change)
B.1.9. Local economy (improve/damage/no change)

B.1.10. Have you made any changes to your cropping system between 2001 & 2005?
Yes/No/NA
B.1.11. What

B.1.12. Why?

B.1.13. Who made the decision?
B.1.14. What was it based on?
Financial/Personal/Others

Do you think it will have an impact on:
B.1.15. Paid labour (increase/decrease/no change)
B.1.16. Unpaid labour (increase/decrease/no change)
B.1.17. Habitat (improve/damage/no change)
B.1.18. Local economy (improve/damage/no change)

B.2. Changes since Single Farm Payments

B.2.1. Have you made any changes to your management since 2005 or are you planning to do so in the next 12 months? Yes/No
B.2.2. What

B.2.3. Why?

B.2.4. What did you base your decision on?
Financial/Personal/Others

Do you think it will have an impact on:
B.2.4. Paid labour (increase/decrease/no change)
B.2.5. Unpaid labour (increase/decrease/no change)
B.2.6. Habitat (improve/damage/no change)
B.2.7. Local economy (improve/damage/no change)

B.2.8. Were these changes a result of the introduction of the SFP? Yes/No/Why?

B.2.9. Do you think that your farming will be constrained/easier/the same following SFP?

Why?

B.2.10. Do you have any long-term plans for your farm? Yes/No/ Which ones?

B.3.11. Did other farmers in your area have major changes on their farms?
(please list)

-
-
-
-
-
-

B.3.12 Do you think it was because of the introduction of the SFP?

B.3.13. Is there some evidence/examples? (please list)

-
-
-
-
-
-

B.3.14. Will it affect your own decisions? Yes/No
B.3.15. Why?

How do you agree or disagree with the following statements regarding the future of hill farming in the area?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
There is no future in hill farming	o	o	o	o	o
There is no future unless there is more support from agri-environmental schemes	o	o	o	o	o
There is no future unless the prices increase substantially	o	o	o	o	o
Diversification is one way of making a better future	o	o	o	o	o
Livestock grazing will be necessary to keep the hills suitable for hill walkers & tourists	o	o	o	o	o
There will be a steady decline until the economic situation improves	o	o	o	o	o
Hill farmers are important contributor to the local economy	o	o	o	o	o
There will be less rural labour without hill farming	o	o	o	o	o

Part C. Your farm in the local area

C.1. How do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
As a farmer, I am a respected member of the local community	o	o	o	o	o
Bad press has undermined farmers' standing in the local community	o	o	o	o	o
Local residents are not sympathetic to farmers and their needs	o	o	o	o	o
Local authorities do not understand farmers and their needs	o	o	o	o	o
Farmers should do more to promote farming interests	o	o	o	o	o

Part D - Additions to Face to Face Interview (from survey questionnaire)

Farm no.:

Date:

D.1. What is the size of your farm (how much do you farm)? ....(ha)

D.2. In 2006, what were your areas of: (ha)

- Inbye ......
- Hill ground ....
- Cereals ....
- Fodder crops ....
- Hay/silage ....
- Other ....

Conifer woodland (ha)

- Of which you manage commercially ....
- Of which you manage non-commercially ....
- Of which you do not manage at all ....

Broadleaved woodland

- Of which you manage commercially ....
- Of which you manage non-commercially ....
- Of which you do not manage at all ....

D.3. Which of the following best describes your tenure?
(tick more than one box if need be)

- ☐ **Tenant**
- ☐ Owner-occupier
- ☐ Mixed
- ☐ Seasonal lets only
- ☐ Contract farmer
- ☐ Other..........................

D.4. Are you mainly;

- ☐ LFA specialist sheep farm
- ☐ LFA specialist beef farm
- ☐ LFA sheep & beef farm
- ☐ Other (please specify):...

Are you a;

- ☐ Sole trader
- ☐ In partnership
- ☐ Company

D.5. Numbers of animals in 2006

How many breeding ewes did you have?
...........(No.) ....(Breed) ....
....
....

How many lambs did you wean (roughly)? ....

How many cattle (and of what type and breed)?
.........................(Type) ....(No.) .... (Breed)
....

What bull do you use? ....

D.6. What do you think is the maximum number of ewes (of your current types) your farm could carry (compared to now)?...

If you don't carry this number, why not? (circle & rank)
Welfare, labour, infrastructure, weather, performance, economics, forage availability, others

D.13. Do you have seasonal grazing?	☐ Contractor ☐ No silage/hay Yes/No

D.14. Other farm activities:

D.14.1. Which of the following activity do you have on the farm?
- Farm shop
- Tourist accommodation (please specify, with places/beds) ....
- Forestry
- Sporting (please specify)
- Phone Mast
- Energy production (eg, hydro-electric, wind)
- Others (detail)

D.14.2. When did you start these other farm activities?

D.14.3. Did you change anything regarding these activities in the past 2 years?
Why?

D.14.4. Please rank in order of importance of income your farm activities
(ie, are you more interested in your forestry than livestock, or do you devote more time on your tourist activity than on your farming activity, etc.?)

D.14.5. How much of your household income comes from farming? (in %)

D.15. What is your personal motivation for carrying on farming/land management in the future? (tick **one** only)

☐ Profitability until you retire

☐ Providing a working system for the next generation

☐ Developing an environmentally friendly system, even though not always profitable

☐ Enjoy farming/land management and will carry on regardless

☐ Other (please specify)...

D.16. Which age-bracket are you in?

☐ 18-30 ☐ 31-45 ☐ 46-60 ☐ Over 60

D.17. What level of education do you have?

o School leaver o Secondary o Higher qualification o University

D.18. How many years have you lived in the area?

D.7. What do you think is the maximum number of cattle (of your current types) your farm could carry (compared to now)?..

If you don't carry this number, why not? (circle & rank)
Welfare, labour, infrastructure, weather, performance, economics, forage availability, others

D.8. How have you come to the number of stock you carry on the farm?
(explain both history and current stocking)
Why?

D.9. Labour – Family labour
How many hours (or % of time) do you spend on:

	Farmer	Partner (wife/husband)	Business partner (son/father/other)
Working on farm			
Working off-farm (farming activity)			
Working off-farm (non-farming)			

Employee/Contractors

- Number of full-time employees ....
- Number of part-time employees? ....
- How many contract workers for how many days? (e.g. 2 contractors approx 60 days per year in total) ....
- What work do the contractors do? ....

D.10. What are your outputs? (tick more than one box if need be);

	%	Where do you sell them? (precise market/abattoir/direct sales)
☐ Hill store lambs	......	....
☐ Cross-bred store lambs	....	....
☐ Finished lambs	....	....
☐ Ewe lambs for breeding	....	....
☐ Tups for breeding	....	....
☐ Draft ewes/pedigree ewes	....	....
☐ Store cattle	....	....
☐ Finished cattle	....	....
☐ Other (please specify)	....	....

D.11. Are you part of a co-operative group to sell your animals?	Yes/No Which ones?
D.12. Did you produce your own hay or use a contractor in 2006? Did you produce your own silage or use a contractor in 2006?	☐ Self ☐ Contractor ☐ No silage/hay ☐ Self

APPENDIX V.

Statistical analysis details for Chapter 5

V.1. Customised genstat programme (written by Sarah Brocklehurst, BioSS)

```
"open file myalldataJan10.GSH"
"open file names.GSH"
"-----------------------------------------------------------------------------------------------"
"1st STEP:"

"preliminary data processing"
"-----------------------------------------------------------------------------------------------"
"run dcscatterprocedure.gen"
"-----------------------------------------------------------------------------------------------"
"preliminary calcs"

calc nofarms=nvalues(farm)
print nofarms
calc alldata=0*farm+1
"---------------------------------------------------------------------------------------------------------------------------------"
"2nd STEP:"

"define variables etc and put into pointers for programming convenience"

"define factors"
calc nofff=107"number of factors"
"put all factor names below"
text [nvalues=nofff;values=('farm','loc','ten','own','sea','confarm','typefarm',\
'mxeww','mxewl','mxewin','mxewwea','mxewper','mxeweeco','mxewf','mxewot','mxcaw','mxcal',\
'mxcain','mxcawea','mxcaper','mxcaeco','mxcaf','mxcaot','cwshe','cwga','cwsc','cwoth','hay','chay',\
'nhay','sil','csil','nsil','seag','fmsh','tou','for','spr','phmst','engy','othdiv','rkfarm','calsprng',\
'calsum','calautu','scan','lambng','cloflo','hqlty','hqty',\
'pkqlty','pkqty','fieqlty','fieqty','hayfieqlty','hayfieqty','distissue','health','vets','comdisease',\
'farmdisease','RSS','ESA','CPS','WGS','LMC','SFGS','OAS','feedew','moti','buynewfl','disrisk','boudisea','resothfarm','builincre','labincre','builfit',\
'builless','otherless','borrow','buyunknow','riskfarm','sysfail','bestqlty','divers','fregardless',\
'profit','nxtgene','effici','impenvt','lesssubs','lessouts','qltytime','nofutu','nofutagr','nofutincre',\
'diverway','livgranec','stedecl','farmcontr','lessrurlab','respect','badpress','localunsym','localunderst',\
'profarming','chgeneigh')] namefff
subset [alldata] farm,loc,ten,own,sea,confarm,typefarm,mxeww,mxewl,\
mxewin,mxewwea,mxewper,mxeweeco,mxewf,mxewot,mxcaw,mxcal,mxcain,mxcawea,mxcaper,mxcaeco,\
mxcaf,mxcaot,cwshe,cwga,cwsc,cwoth,hay,chay,nhay,sil,csil,nsil,seag,fmsh,tou,for,\
spr,phmst,engy,othdiv,rkfarm,calsprng,calsum,calautu,scan,lambng,\
cloflo,hqlty,hqty,pkqlty,pkqty,fieqlty,fieqty,hayfieqlty,hayfieqty,\
distissue,health,vets,comdisease,farmdisease,RSS,ESA,CPS,WGS,LMC,SFGS,OAS,feedew,moti,buynewfl,disrisk,boudisea,resothfarm,builincre,
labincre,builfit,builless,otherless,borrow,buyunknow,riskfarm,sysfail,bestqlty,divers,fregardless,\
profit,nxtgene,effici,impenvt,lesssubs,lessouts,qltytime,nofutu,nofutagr,nofutincre,\
diverway,livgranec,stedecl,farmcontr,lessrurlab,respect,badpress,localunsym,localunderst,\
profarming,chgeneigh;fff[1...nofff]
variate [nvalues=1] pnlevfff[1...nofff]
calc vfff[1...nofff]=fff[1...nofff]
getattribute [attribute=levels,labels,nlevels] fff[1...nofff];atffff[1...nofff]
calc pnlevfff[1...nofff]=atffff[1...nofff]['nlevels']
"1: continous, 2: binary, or c: categorical with c levels"
variate [nvalues=nofff] typeoffff
equate old=pnlevfff;new=typeoffff
variate [nvalues=nofff; value=(1...nofff)] whichfff
fspreadsheet whichfff,namefff,typeoffff
"put names into pointer"
text [nvalues=1] pnamefff[1...nofff]
equate old=namefff; new=pnamefff
"put types into pointer"
variate [nvalues=1] ptypeoffff[1...nofff]
equate old=typeoffff; new=ptypeoffff

"define variables"
calc novvv=42"number of variates"
"put all variate names below"
calc vvv[1...novvv]=inhill,prode1,SR,noewe1,noewe2,lam1,lam2,catt1,mxew1,mxca,fwonf,\
fwoff,fwofnf,wwonf,wwoff,wwofnf,pwonf,pwoff,pwofnf,fte,pte,conwk,dconwk,noponf,shlab,\
```

```
livlab,%st,%cb,%f,%eb,%tb,%de,%stca,%fca,%oth,longga,shorga,nogather,peobiga,peosmga,\
longfeed,shorfeed
text [nvalues=novvv;values=('inhill','prode1','SR','noewe1','noewe2','lam1','lam2','catt1',\
'mxew1','mxca','fwonf','fwoff','fwofnf','wwonf','wwoff','wwofnf','pwonf','pwoff','pwofnf','fte',\
'pte','conwk','dconwk','noponf','shlab','livlab','%st','%cb','%f','%eb','%tb','%de','%stca','%fca',\
'%oth','longga','shorga','nogather','peobiga','peosmga','longfeed','shorfeed')] namevvv
"1: continous, 2: binary, or c: categorical with c levels"
variate [nvalues=novvv;values=#novvv(1)] typeofvvv
variate [nvalues=novvv; value=(1...novvv)] whichvvv
fspreadsheet whichvvv,namevvv,typeofvvv
"put names into pointer"
text [nvalues=1] pnamevvv[1...novvv]
equate old=namevvv; new=pnamevvv
"put types into pointer"
variate [nvalues=1] ptypeofvvv[1...novvv]
equate old=typeofvvv; new=ptypeofvvv
```

"***define xxx***" *(new covariates)*

```
calc noxxx=novvv+nofff
calc xxx[1...noxxx]=vvv[1...novvv],vfff[1...nofff]
text [nvalues=noxxx] namexxx
append [namexxx] namevvv,namefff
variate [nvalues=noxxx] typeofxxx
append [typeofxxx] typeofvvv,typeoffff
"just a variate indicating the variable no (coxxx)"
variate [nvalues=noxxx; value=(1...noxxx)] whichxxx
fspreadsheet whichxxx,typeofxxx,namexxx
"put names into pointer"
text [nvalues=1] pnamexxx[1...noxxx]
equate old=namexxx; new=pnamexxx
"put types into pointer"
variate [nvalues=1] ptypeofxxx[1...noxxx]
equate old=typeofxxx; new=ptypeofxxx
```

"***create a dummy factor with a single level to be used in trellis plots, since trellis will not run unless you give it a factor for different frames (different graphs) and sometimes you may want graphs with only one frame (see later)"***

```
calc lenxxx=nvalues(xxx[1])
variate [nvalues=lenxxx;values=#lenxxx(1)] dummy
groups dummy;fdummy
text [nvalues=nofarms] tfarm
equate old=farm;new=tfarm
fspreadsheet tfarm

"------------------------------------------------------------------------------------------------------------------------------"
```

“3rd STEP:”

"relationships between variables - correlations"

```
delete [redefine=yes] corr,pcorr
CORRELATE [PRINT=*; CORRELATIONS=corr] xxx[1...noxxx]
FSPREADSHEET corr
DELETE [REDEFINE=yes] _clprob, _cuprob, _probs
PRCORRELATION [NOBS=NVAL(xxx[1])] ABS(corr); CLPROB=_clprob; CUPROB=_cuprob
DELETE [REDEFINE=yes] pcorr
SYMMETRIC [ROWS=!p(xxx[1...noxxx])] pcorr; EXTRA='Probabilites'
CALC pcorr = 1 - _clprob + _cuprob
FSPREADSHEET pcorr
"------------------------------------------------------------------------------------------------------------------------------"
```

“4th STEP:”

"**clustering of farms**" “*(first quick analysis)”*

"***construct similarity matrix***"

```
"------------------------------------------------------------------------------------------------------------------------"
"get similarity matrices for each xxx"
for coxxx=1...noxxx
  DELETE [Redefine=yes] sim[coxxx]
  if ptypeofxxx[coxxx].gt.1
    FSIMILARITY [SIMILARITY=sim[coxxx];UNITS=tfarm] xxx[coxxx]; TEST=simplematching
  else
    FSIMILARITY [SIMILARITY=sim[coxxx];UNITS=tfarm] xxx[coxxx]; TEST=Euclidean
  endif
  "fspreadsheet sim[coxxx]"
endfor "coxxx"

"fspreadsheet sim[5]" "say, if you want to see farm by farm matrix for one var or factor"
"------------------------------------------------------------------------------------------------------------------------"
```

"***get weights for contribution to overall similarity matrix of each farm covariate - assuming equal weights***"

```
calc wgtmethod=1
variate [nvalues=noxxx] vwgt
scalar wgt[1...noxxx]
calc wgt[1...noxxx]=1/noxxx"THIS COULD BE ALTERED (BUT THEY MUST SUM TO 1) IF YOU WANT TO MAKE SOME
COVARIATE/FACTOR MORE IMPORTANT THAN OTHERS"
```

```
equate old=wgt;new=vwgt
fspreadsheet vwgt
calc sumwgts=sum(vwgt)
print sumwgts
"----------------------------------------------------------------------------------------------------------------------------"
"calc similarity matrix according to above weights"
calc simil=0*sim[1]
calc totwgt=0
for coxxx=1...noxxx
  calc simil=simil+wgt[coxxx]*sim[coxxx]
endfor
"take care of rounding errors on diagonal (1 was actually 0.9999999....):"
calc simil=simil-simil*(simil.eq.1)+1*(simil.eq.1)"######"
fspreadsheet simil
"THIS SHOWS SIMILARITY BETWEEN PAIRS OR FARMS"

"----------------------------------------------------------------------------------------------------------------------------"
"examine dendogram for HCA based on original similarity matrix - ie startmethod=3"
HCLUSTER [METHOD=nearestneighbour] simil;permutation=_perm
GETATTRIBUTE [ATTRIBUTE=rows] simil; _ps
HDISPLAY [PRINT=*] simil; TREE=_ddmst
DDENDROGRAM [ORDER=given; DSIMILARITY=yes] DATA=_ddmst; PERM=_perm; WINDOW=1; LABELS=tfarm
"THIS IS A QUICK CLUSTER TO SHOW DENDOGRAM"

"----------------------------------------------------------------------------------------------------------------------------"
"5th STEP:"

"carry out principal coordinates analysis on similarity matrix"

"----------------------------------------------------------------------------------------------------------------------------"
"setting for PCO and nHCA"

"set number of pco roots initially investigated"
calc maxnoofroots=10

"set max accumulated % of roots for further investigation"
calc maxpcoaccpercforgraphsetc=100
"set max number of roots for further investigation"
calc maxnorootsforgraphsetc=5"######" "this can be changed depending how many roots we want to investigate"

"set accumulated % of roots included for clustering"
calc maxpcoaccpercforclusteranal=100
"set min number of roots included for clustering"
calc minnorootsforclusteranal=2
"set max number of roots included for clustering"
calc maxnorootsforclusteranal=5"######" "this can be changed depending how many roots we want to investigate"
"set minimum and maximum number of grps for the cluster analysis"
calc minnogrps=2
calc maxnogrps=9
"set min and max start method for cluster analysis:"
calc minstartmethod=1
calc maxstartmethod=1
"1: use classify"
"2: use HCA results on pcos to be included for cluster as start"
"3: use HCA results on original similarity matrix as start"
"----------------------------------------------------------------------------------------------------------------------------"
"work out how many pco roots are positive"
calc noroots=maxnoofroots
DELETE [REDEFINE=YES] pcolatrootvect,pcodistances,rootno,pcoroots
PCO [PRINT=*; NROOTS=noroots] simil; LRV=pcolatrootvect; DISTANCES=pcodistances
"FSPREADSHEET pcolatrootvect['Vectors']
FSPREADSHEET pcolatrootvect['Roots']
FSPREADSHEET pcolatrootvect['Trace']
FSPREADSHEET pcodistances"
variate [nvalues=noroots;values=1...noroots] rootno
variate [nvalues=noroots] pcoroots
equate old=pcolatrootvect['Roots'];new=pcoroots
"fspreadsheet rootno,pcoroots"
calc posstoprootno=max(rootno*(pcoroots.gt.0))
print 'number of positive roots from pco: ',posstoprootno

"----------------------------------------------------------------------------------------------------------------------------"
"examine % variation for all positive roots"
calc noroots=posstoprootno
DELETE [REDEFINE=YES] pcolatrootvect,pcodistances,rootno,pcoroots,pcopercvar,pcoaccpercvar,ppcopercvar,ppcoaccpercvar
PCO [PRINT=roots,scores; NROOTS=noroots] simil; LRV=pcolatrootvect; DISTANCES=pcodistances
"FSPREADSHEET pcolatrootvect['Vectors']
FSPREADSHEET pcolatrootvect['Roots']
FSPREADSHEET pcolatrootvect['Trace']
FSPREADSHEET pcodistances"
variate [nvalues=noroots;values=1...noroots] rootno
variate [nvalues=noroots] pcoroots,pcopercvar,pcoaccpercvar
variate [nvalues=1] ppcopercvar[1...noroots],ppcoaccpercvar[1...noroots]
```

```
equate old=pcolatrootvect['Roots'];new=pcoroots
calc pcopercvar=100*pcoroots/sum(pcoroots)
equate old=pcopercvar;new=ppcopercvar
calc pcoaccpercvar=0*pcopercvar
calc ppcoaccpercvar[1]=ppcopercvar[1]
for coroot=2...noroots
  calc colastroot=coroot-1
  calc ppcoaccpercvar[coroot]=ppcoaccpercvar[colastroot]+ppcopercvar[coroot]
endfor
equate old=ppcoaccpercvar;new=pcoaccpercvar
fspreadsheet rootno,pcoroots,pcopercvar,pcoaccpercvar
"plot % variation versus root number"
FRAME [RESET=yes] WINDOW=1; BOX=omit
XAXIS [RESET=yes] WINDOW=1; TITLE='rootno'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=parallel; MPOSITION=outside; ARROWHEAD=omit; ACTION=display; marks=1
YAXIS [RESET=yes] WINDOW=1; TITLE='pcopercvar'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=perpendicular; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
"Set colours for plotting"
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15; RED=3(128),192,255,2(128); GREEN=128,\
0,64,0,4(128); BLUE=2(128,0),128,2(192),128
PEN [RESET=yes] 1; METHOD=line; SYMBOL=2; SIZE=1; CSYMBOL=2
DGRAPH [WINDOW=1; TITLE='% var vs root no'] Y=pcopercvar; X=rootno; PEN=1
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15
PEN [RESET=yes] 1
"plot accumulated % variation versus root number"
FRAME [RESET=yes] WINDOW=1; BOX=omit
XAXIS [RESET=yes] WINDOW=1; TITLE='rootno'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=parallel; MPOSITION=outside; ARROWHEAD=omit; ACTION=display; marks=1
YAXIS [RESET=yes] WINDOW=1; TITLE='accpcopercvar'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=perpendicular; MPOSITION=outside; ARROWHEAD=omit; ACTION=display; lower=0; upper=105
"Set colours for plotting"
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15; RED=3(128),192,255,2(128); GREEN=128,\
0,64,0,4(128); BLUE=2(128,0),128,2(192),128
PEN [RESET=yes] 1; METHOD=line; SYMBOL=2; SIZE=1; CSYMBOL=2
DGRAPH [WINDOW=1; TITLE='accumulated % var vs root no'] Y=pcoaccpercvar; X=rootno; PEN=1
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15
PEN [RESET=yes] 1

"------------------------------------------------------------------------------------------------------------------------"
"further investigation of pcoscores"
"you have to run this section before doing cluster analysis"

calc invstoprootno=max(rootno*(pcoaccpercvar.lt.maxpcoaccpercforgraphsetc)-10000*(pcoaccpercvar.gt.maxpcoaccpercforgraphsetc))
calc
invstoprootno=invstoprootno*(invstoprootno.lt.maxnorootsforgraphsetc)+maxnorootsforgraphsetc*(invstoprootno.ge.maxnorootsforgraphsetc)
print 'number of roots for further investigation: ',invstoprootno

"------------------------------------------------------------------------------------------------------------------------"
"examine pcos up to stoprootno"
"you have to run this section before doing cluster analysis"

calc noroots=invstoprootno
DELETE [REDEFINE=YES] pcolatrootvect,pcodistances,pcoscores,matpcoscores,trmatpcoscores
PCO [PRINT=roots, scores, residuals, centroid; NROOTS=noroots] simil; LRV=pcolatrootvect; DISTANCES=pcodistances
variate [nvalues=nofarms] pcoscores[1...noroots]
matrix [columns=noroots;rows=nofarms] matpcoscores
equate old=pcolatrootvect['Vectors'];new=matpcoscores
calc trmatpcoscores=transpose(matpcoscores)
equate old=trmatpcoscores;new=pcoscores
fspreadsheet pcoscores[1...noroots]

"get labelling for pcscores to be used in plots"
variate [nvalues=noroots;values=(1...noroots)] vshortnamepcoscores
ftext vshortnamepcoscores;shortnamepcoscores
variate [nvalues=noroots;values=(noroots...1)] indextosortwith
sort [index=indextosortwith] old=shortnamepcoscores;new=revshortnamepcoscores
"------------------------------------------------------------------------------------------------------------------------"
"various plots of pcscores"
"------------------------------------------------------------------------------------------------------------------------"
"to plot pcscores labelled by farms"

PEN 1...nofarms; LABELS=tfarm;symbol=2; size=0.7
dcscatter [pcoscores[1...noroots];shortnamepcoscores;ticksandlabels=no";equal=yes";pen=farm]\
 pcoscores[noroots...1];revshortnamepcoscores

"------------------------------------------------------------------------------------------------------------------------"
"3d plot of first 3 pcos only"
"you can change code to do other pcoscores - e.g. 1,2,4; 2,3,4 etc"
"you can rotate this plot in 3d to see if there is obvious 3d clustering"
FRAME [RESET=yes] WINDOW=1; BOX=include
XAXIS [RESET=yes] WINDOW=1; TITLE='pcoscores[1]'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=parallel; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
YAXIS [RESET=yes] WINDOW=1; TITLE='pcoscores[2]'; TPOSITION=middle; TDIRECTION=parallel;\
```

```
 LPOSITION=outside; LDIRECTION=perpendicular; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
ZAXIS [RESET=yes] WINDOW=1; TITLE='pcoscores[3]'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=perpendicular; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
"Set colours for plotting"
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15; RED=3(128),192,255,2(128); GREEN=128,\
0,64,0,4(128); BLUE=2(128,0),128,2(192),128
VARIATE _scolour; !(1,2,3,4,30,7,5,6,12,8)
VARIATE _symb; !(-1,-1,-1,-1,-1,-1,-1,-1,-1,-1)
VARIATE _symsize; !(1,1,1,1,1,1,1,1,1,1)
PEN [RESET=yes] 1...nofarms; METHOD=point; SYMBOL=#_symb; SIZE=#_symsize; CSYMBOL=#_scolour
D3GRAPH [WINDOW=1; TITLE='first 3 pcos'; AZIMUTH=225; ELEVATION=25] X=pcoscores[1]; Y=pcoscores[2]; Z=pcoscores[3];
PEN=farm
PEN [RESET=yes] 1...nofarms
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15

"-------------------------------------------------------------------------------------------------------------------------"
"examination of which xxx (covariates) are related to which pcoscores"

delete [redefine=yes] corr,pcorr
CORRELATE [PRINT=*; CORRELATIONS=corr] xxx[1...noxxx],pcoscores[1...noroots]
FSPREADSHEET corr
DELETE [REDEFINE=yes] _clprob, _cuprob, _probs
PRCORRELATION [NOBS=NVAL(xxx[1])] ABS(corr); CLPROB=_clprob; CUPROB=_cuprob
DELETE [REDEFINE=yes] pcorr
SYMMETRIC [ROWS=!p(xxx[1...noxxx],pcoscores[1...noroots])] pcorr; EXTRA='Probabilites'
CALC pcorr = 1 - _clprob + _cuprob
FSPREADSHEET pcorr

PEN [RESET=yes] 1...nofarms
PEN 1...nofarms; LABELS=tfarm;symbol=2; size=0.6
text [nvalues=5] tempnamexxx
append [tempnamexxx] pnamexxx[1...5]
dcscatter [xxx[1...5];tempnamexxx;ticksandlabels=no";equal=yes";pen=farm]\
  pcoscores[noroots...1];revshortnamepcoscores
append [tempnamexxx] pnamexxx[6...10]
dcscatter [xxx[6...10];tempnamexxx;ticksandlabels=no";equal=yes";pen=farm]\
  pcoscores[noroots...1];revshortnamepcoscores
append [tempnamexxx] pnamexxx[11...15]
dcscatter [xxx[11...15];tempnamexxx;ticksandlabels=no";equal=yes";pen=farm]\
  pcoscores[noroots...1];revshortnamepcoscores
append [tempnamexxx] pnamexxx[16...20]
dcscatter [xxx[16...20];tempnamexxx;ticksandlabels=no";equal=yes";pen=farm]\
  pcoscores[noroots...1];revshortnamepcoscores
append [tempnamexxx] pnamexxx[21...25]
dcscatter [xxx[21...25];tempnamexxx;ticksandlabels=no";equal=yes";pen=farm]\
  pcoscores[noroots...1];revshortnamepcoscores
append [tempnamexxx] pnamexxx[26...31]
dcscatter [xxx[26...31];tempnamexxx;ticksandlabels=no";equal=yes";pen=farm]\
  pcoscores[noroots...1];revshortnamepcoscores


"-------------------------------------------------------------------------------------------------------------------------"
"6th STEP:"

"carry out non hierarchical cluster analysis (nHCA) on pcoscores"

"-------------------------------------------------------------------------------------------------------------------------"
calc cluststoprootno=max(rootno*(pcoaccpercvar.lt.maxpcoaccpercforclusteranal)-10000*(pcoaccpercvar.gt.maxpcoaccpercforclusteranal))
calc cluststoprootno=cluststoprootno*(cluststoprootno.lt.maxnorootsforclusteranal)\
+maxnorootsforclusteranal*(cluststoprootno.ge.maxnorootsforclusteranal)
print 'maximum number of roots for clustering: ',cluststoprootno

if (cluststoprootno.gt.invstoprootno)
  print 'you cannot have max number of pcoscores for cluster analysis exceeding those investigated further!!!'
  print invstoprootno,cluststoprootno
endif

"nonHCA"
calc minnoroots=minnorootsforclusteranal
calc maxnoroots=cluststoprootno

delete [redefine=yes] startgrping,fstartgrping
calc caseno=0
for conoroots=minnoroots...maxnoroots
for cogroups=minnogrps...maxnogrps
for startmethod=minstartmethod...maxstartmethod
  calc caseno=caseno+1
  print caseno
  calc phcastartfailed[caseno]=0
  text [nvalues=1;values='simplematcheucl'] psimmethod[caseno]
  calc pwgtmethod[caseno]=wgtmethod
  calc pnoroots[caseno]=conoroots
  calc pngrps[caseno]=cogroups
```

```
  calc pstartmethod[caseno]=startmethod
  text [nvalues=1;values='sums'] pcritmethod[caseno]
  if startmethod.eq.1"start cluster by using classify"
    FACTOR _start
    CLASSIFY !p(pcoscores[1...conoroots]); NGROUPS=cogroups; GROUPS=_start
    calc startgrping[caseno]=_start
  endif
  if startmethod.eq.2"start cluster by using results from HCA based on Eucl similarity from pcos"
    DELETE [Redefine=yes] similpco
    FSIMILARITY [SIMILARITY=similpco;UNITS=tspeciesid] pcoscores[1...conoroots]; TEST=euclidean
    calc foundstart=0
    for cothresh=10000...9000
      calc theshold=cothresh/100
      HCLUSTER [METHOD=nearestneighbour] similpco; groups=hcsgroups; gthreshold=theshold
      "fspreadsheet hcsgroups"
      if (nlevels(hcsgroups).eq.cogroups)
        calc startgrping[caseno]=hcsgroups
        print 'found hca start ',theshold
        calc foundstart=1
      endif
    endfor
    if foundstart.eq.0
      print 'no HCA soln found for cocase ',caseno
      calc phcastartfailed[caseno]=1
      FACTOR _start
      CLASSIFY !p(pcoscores[1...conoroots]); NGROUPS=cogroups; GROUPS=_start
      calc startgrping[caseno]=_start
    endif
  endif
  if startmethod.eq.3"start cluster by using results from HCA based on original similarity matrix"
    calc foundstart=0
    for cothresh=9500...7200
      calc theshold=cothresh/100
      HCLUSTER [METHOD=nearestneighbour] simil; groups=hcsgroups; gthreshold=theshold
      "fspreadsheet hcsgroups"
      if (nlevels(hcsgroups).eq.cogroups)
        calc startgrping[caseno]=hcsgroups
        print 'found hca start ',theshold
        calc foundstart=1
      endif
    endfor
    if foundstart.eq.0
      print 'no HCA soln found for cocase ',caseno
      calc phcastartfailed[caseno]=1
      FACTOR _start
      CLASSIFY !p(pcoscores[1...conoroots]); NGROUPS=cogroups; GROUPS=_start
      calc startgrping[caseno]=_start
    endif
  endif
  if startmethod.eq.4"start cluster by using classification as in grppriorbelief"
    calc startgrping[caseno]=grppriorbelief
  endif
  groups startgrping[caseno];fstartgrping[caseno]
  "find within group SofS for start grouping"
  delete [redefine=yes] nobspcoscores,tnobspcoscores,varpcoscores,tvarpcoscores,sospcoscores,initcritvalpergrp
  variate [nvalues=cogroups] nobspcoscores[1...conoroots],varpcoscores[1...conoroots]
  tabulate [classification=fstartgrping[caseno]]
pcoscores[1...conoroots];var=tvarpcoscores[1...conoroots];nobservations=tnobspcoscores[1...conoroots]
  equate old=tnobspcoscores[1...conoroots];new=nobspcoscores[1...conoroots]
  equate old=tvarpcoscores[1...conoroots];new=varpcoscores[1...conoroots]
  calc sospcoscores[1...conoroots]=varpcoscores[1...conoroots]*(nobspcoscores[1...conoroots]-1)
  "fspreadsheet sospcoscores[1...conoroots]"
  calc initcritvalpergrp=vsum(sospcoscores)
  "fspreadsheet initcritvalpergrp"
  calc pinitcritval[caseno]=sum(initcritvalpergrp)
  CLUSTER [PRINT=criterion,optimum,units,typical,initial;DATA=!p(pcoscores[1...conoroots]); CRITERION=sums;\
  INTERCHANGE=transfer; START=fstartgrping[caseno]] NGROUPS=cogroups; GROUPS=grpnhca[caseno]
  "find within group SofS for final grouping"
  delete [redefine=yes] nobspcoscores,tnobspcoscores,varpcoscores,tvarpcoscores,sospcoscores,critvalpergrp
  variate [nvalues=cogroups] nobspcoscores[1...conoroots],varpcoscores[1...conoroots]
  tabulate [classification=grpnhca[caseno]]
pcoscores[1...conoroots];var=tvarpcoscores[1...conoroots];nobservations=tnobspcoscores[1...conoroots]
  equate old=tnobspcoscores[1...conoroots];new=nobspcoscores[1...conoroots]
  equate old=tvarpcoscores[1...conoroots];new=varpcoscores[1...conoroots]
  calc sospcoscores[1...conoroots]=varpcoscores[1...conoroots]*(nobspcoscores[1...conoroots]-1)
  "fspreadsheet sospcoscores[1...conoroots]"
  calc critvalpergrp=vsum(sospcoscores)
  "fspreadsheet initcritvalpergrp"
  calc pcritval[caseno]=sum(critvalpergrp)
  "find total SofS"
  delete [redefine=yes] totsospcoscores
  calc totsospcoscores[1...conoroots]=(nofarms-1)*variance(pcoscores[1...conoroots])
  calc ptotsos[caseno]=vsum(totsospcoscores)
```

```
  calc ppercinitcritoftotsos[caseno]=100*(1-(pinitcritval[caseno]/ptotsos[caseno]))
  calc pperccritoftotsos[caseno]=100*(1-(pcritval[caseno]/ptotsos[caseno]))
endfor "startmethod"
endfor "cogroups"
endfor "coconoroots"

calc maxcaseno=caseno
calc pcaseno[1...maxcaseno]=1...maxcaseno
ftext pcaseno[1...maxcaseno];tpcaseno[1...maxcaseno]
ftext pwgtmethod[1...maxcaseno];tpwgtmethod[1...maxcaseno]
ftext pnoroots[1...maxcaseno];tpnoroots[1...maxcaseno]
ftext pngrps[1...maxcaseno];tpngrps[1...maxcaseno]
ftext pstartmethod[1...maxcaseno];tpstartmethod[1...maxcaseno]
ftext phcastartfailed[1...maxcaseno];tphcastartfailed[1...maxcaseno]
ftext ptotsos[1...maxcaseno];tptotsos[1...maxcaseno]
ftext pinitcritval[1...maxcaseno];tpinitcritval[1...maxcaseno]
ftext pcritval[1...maxcaseno];tpcritval[1...maxcaseno]
ftext ppercinitcritoftotsos[1...maxcaseno];tppercinitcritoftotsos[1...maxcaseno]
ftext pperccritoftotsos[1...maxcaseno];tpperccritoftotsos[1...maxcaseno]

text [nvalues=13;values=('caseno','simmethod','wgtmethod','noroots','nogrps','startmethod','hcastartfail','critmethod',\
'totsos','initcritval','critval','percinitcritval','perccritval')] details

for cocaseno=1...maxcaseno
  append [newvector=settings[cocaseno]] oldvector=tpcaseno[cocaseno],psimmethod[cocaseno],tpwgtmethod[cocaseno],tpnoroots[cocaseno],\
  tpngrps[cocaseno],tpstartmethod[cocaseno],tphcastartfailed[cocaseno],pcritmethod[cocaseno],tptotsos[cocaseno],\
  tpinitcritval[cocaseno],tpcritval[cocaseno],tppercinitcritoftotsos[cocaseno],tpperccritoftotsos[cocaseno]
endfor

fspreadsheet details,settings[1...maxcaseno]
fspreadsheet fstartgrping[1...maxcaseno],grpnhca[1...maxcaseno]


"plot %sos explained versus caseno"
variate [nvalues=maxcaseno;values=(1...maxcaseno)] vcaseno
variate [nvalues=maxcaseno] vperccritoftotsos
equate old=pperccritoftotsos;new=vperccritoftotsos
FRAME [RESET=yes] WINDOW=1; BOX=omit
XAXIS [RESET=yes] WINDOW=1; TITLE='vcaseno'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=parallel; MPOSITION=outside; MARKS=1; ARROWHEAD=omit;\
 ACTION=display
YAXIS [RESET=yes] WINDOW=1; TITLE='vperccritoftotsos'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=perpendicular; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
"Set colours for plotting"
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15; RED=3(128),192,255,2(128); GREEN=128,\
0,64,0,4(128); BLUE=2(128,0),128,2(192),128
PEN [RESET=yes] 1; METHOD=line; JOIN=ascending; SYMBOL=0; LINESTYLE=1; THICKNESS=1;\
 SIZE=1; CLINE=1
DGRAPH [WINDOW=1; TITLE='% sos'] Y=vperccritoftotsos; X=vcaseno; PEN=1
PEN [RESET=yes] 1
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15

"------------------------------------------------------------------------------------------------------------------------"
"examine pcoscores with cluster groups for chosen casenumbers"

calc thiscaseno=26"change this as required""######"

fspreadsheet tfarm,grpnhca[thiscaseno]

"resort by chosen clustering"
delete [redefine=yes] sortgrpnhca,sorttfarm,sortxxx[1...noxxx]
sort [index=grpnhca[thiscaseno],farm] grpnhca[thiscaseno],tfarm,xxx[1...noxxx];\
sortgrpnhca,sorttfarm,sortxxx[1...noxxx]
fspreadsheet sortgrpnhca,sorttfarm,sortxxx[1...noxxx]

"to plot all pcs by cluster groups"
calc noroots=pnoroots[thiscaseno]
calc nlevgrpnhca=nlevels(grpnhca[thiscaseno])
variate [nvalues=noroots;values=(1...noroots)] tempvshortnamepcoscores
ftext tempvshortnamepcoscores;tempshortnamepcoscores
variate [nvalues=noroots;values=(noroots...1)] tempindextosortwith
sort [index=tempindextosortwith] old=tempshortnamepcoscores;new=temprevshortnamepcoscores
PEN [RESET=yes] 1...nlevgrpnhca
PEN 1...nlevgrpnhca; LABELS=*;symbol=2; size=0.7
dcscatter [pcoscores[1...noroots];tempshortnamepcoscores;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
 pcoscores[noroots...1];temprevshortnamepcoscores
"include species labelling"
PEN [RESET=yes] 1...nlevgrpnhca
PEN 1...nlevgrpnhca; LABELS=tfarm;symbol=2; size=0.7
dcscatter [pcoscores[1...noroots];tempshortnamepcoscores;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
 pcoscores[noroots...1];temprevshortnamepcoscores
delete [redefine=yes] tempvshortnamepcoscores,tempshortnamepcoscores,tempindextosortwith,temprevshortnamepcoscores
```

"to plot all pcs by cluster groups - one pair of pcscores at a time"

```
calc noroots=pnoroots[thiscaseno]
calc nlevgrpnhca=nlevels(grpnhca[thiscaseno])
PEN [RESET=yes] 1...nlevgrpnhca
PEN 1...nlevgrpnhca; LABELS=tfarm;symbol=2; size=1
calc topcoroot1=noroots-1
for coroot1=topcoroot1...1
  ftext coroot1;tcoroot1
  calc botcoroot2=coroot1+1
  for coroot2=noroots...botcoroot2
    ftext coroot2;tcoroot2
    dcscatter [pcoscores[coroot1];tcoroot1;ticksandlabels=yes";equal=yes";pen=grpnhca[thiscaseno]]\
    pcoscores[coroot2];tcoroot2
  endfor"coroot2"
endfor"coroot1"
```

"3d plot of first 3 pcos only"

"you can change code to do other pcoscores - e.g. 1,2,4; 2,3,4 etc"
"you can rotate this plot in 3d to see if there is obvious 3d clustering"

```
calc nlevgrpnhca=nlevels(grpnhca[thiscaseno])
PEN [RESET=yes] 1...nlevgrpnhca
FRAME [RESET=yes] WINDOW=1; BOX=omit
XAXIS [RESET=yes] WINDOW=1; TITLE='pcoscores[1]'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=parallel; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
YAXIS [RESET=yes] WINDOW=1; TITLE='pcoscores[2]'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=perpendicular; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
ZAXIS [RESET=yes] WINDOW=1; TITLE='pcoscores[3]'; TPOSITION=middle; TDIRECTION=parallel;\
 LPOSITION=outside; LDIRECTION=perpendicular; MPOSITION=outside; ARROWHEAD=omit; ACTION=display
"Set colours for plotting"
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15; RED=3(128),192,255,2(128); GREEN=128,\
0,64,0,4(128); BLUE=2(128,0),128,2(192),128
VARIATE _scolour; !(1,2,3,4,30,7,5)
VARIATE _symb; !(-1,-1,-1,-1,-1,-1,-1)
VARIATE _symsize; !(1,1,1,1,1,1,1)
PEN [RESET=yes] 1...nlevgrpnhca; METHOD=point; SYMBOL=#_symb; SIZE=#_symsize; CSYMBOL=#_scolour
D3GRAPH [WINDOW=1; TITLE='pc1 pc2 pc3'; AZIMUTH=225; ELEVATION=25] X=pcoscores[1]\
; Y=pcoscores[2]; Z=pcoscores[3]; PEN=grpnhca[thiscaseno]
PEN [RESET=yes] 1...nlevgrpnhca
COLOUR [RESET=yes] 30,12,16,22,11,25,27,15
```

"examine clusters in relation to xxx (original covariates)"

```
calc noroots=pnoroots[thiscaseno]
calc nlevgrpnhca=nlevels(grpnhca[thiscaseno])
variate [nvalues=noroots;values=(1...noroots)] tempvshortnamepcoscores
ftext tempvshortnamepcoscores;tempshortnamepcoscores
variate [nvalues=noroots;values=(noroots...1)] tempindextosortwith
sort [index=tempindextosortwith] old=tempshortnamepcoscores;new=temprevshortnamepcoscores
PEN [RESET=yes] 1...nlevgrpnhca
pen 1...nlevgrpnhca; LABELS=tfarm;symbol=2;size=0.6
text [nvalues=5] tempnamexxx
append [tempnamexxx] pnamexxx[1...5]
dcscatter [xxx[1...5];tempnamexxx;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
pcoscores[noroots...1];temprevshortnamepcoscores
append [tempnamexxx] pnamexxx[6...10]
dcscatter [xxx[6...10];tempnamexxx;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
pcoscores[noroots...1];temprevshortnamepcoscores
append [tempnamexxx] pnamexxx[11...15]
dcscatter [xxx[11...15];tempnamexxx;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
pcoscores[noroots...1];temprevshortnamepcoscores
append [tempnamexxx] pnamexxx[16...20]
dcscatter [xxx[16...20];tempnamexxx;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
pcoscores[noroots...1];temprevshortnamepcoscores
append [tempnamexxx] pnamexxx[21...25]
dcscatter [xxx[21...25];tempnamexxx;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
pcoscores[noroots...1];temprevshortnamepcoscores
append [tempnamexxx] pnamexxx[26...31]
dcscatter [xxx[26...31];tempnamexxx;ticksandlabels=no";equal=yes";pen=grpnhca[thiscaseno]]\
pcoscores[noroots...1];temprevshortnamepcoscores
```

"tables of xxx (covariates) by cluster groups"

```
delete [redefine=yes] tcogrpnhcaftrait,tcogrpnhca
tabulate [classification=grpnhca[thiscaseno];counts=tcogrpnhca]
fspreadsheet tcogrpnhca
for coxxx=1...noxxx
  tabulate [classification=grpnhca[thiscaseno]] xxx[coxxx];means=tmeansxxxbygrpnhca[coxxx]
  "fspreadsheet tmeansgrpnhcaftrait[cotrait]"
endfor"coxxx"
fspreadsheet tmeansxxxbygrpnhca
```

"useful to add tables here to show factors by clusters"

V.2. List of final variables (149 in total)

Whichxxx	typeofxxx	namexxx	details
1	1	inhill	Ratio inbye/hill
2	1	prode1	productivity ewes1
3	1	SR	LU per ha
4	1	noewe1	number of ewes1
5	1	noewe2	number of ewes2
6	1	lam1	number of lambs1
7	1	lam2	number of lambs 2
8	1	catt1	number of cattle 1
9	1	mxew1	max number of ewes
10	1	mxca	max number of cattle
11	1	fwonf	Farmer working on farm
12	1	fwoff	Farmer working off farm
13	1	fwofnf	Farmer working off farm - non farming
14	1	wwonf	Partner working on farm
15	1	wwoff	Partner working off farm
16	1	wwofnf	Partner working off farm - non farming
17	1	pwonf	Business partner working on farm
18	1	pwoff	Business partner working off farm
19	1	pwofnf	Business partner working off farm - non farming
20	1	fte	Number of full time employees
21	1	pte	Number of part-time employees
22	1	conwk	Number contract workers
23	1	dconwk	number of days contractors work
24	1	noponf	number people/farmer on farm
25	1	shlab	sheep/labour unit
26	1	livlab	livestock/labour unit
27	1	%st	% hill store lambs sold
28	1	%cb	% cross bred store lambs sold
29	1	%f	% finished lambs sold
30	1	%eb	% ewe lambs for breeding sold
31	1	%tb	% tups for breeding sold
32	1	%de	% draft ewes/pedigree ewes sold
33	1	%stca	% store cattle sold
34	1	%fca	% finished cattle sold
35	1	%oth	% other sold (specify)
36	1	longga	Longest gather (hours)
37	1	shorga	Shortest gather (in hours)
38	1	nogather	How many gathers
39	1	peobiga	number of people for biggest gather
40	1	peosmga	number of people for smallest gather
41	1	longfeed	Longest to feed (hours)
42	1	shorfeed	shortest to feed
43	30	farm	farm no
44	5	loc	location of farm (area)
45	2	ten	tenant
46	2	own	owner-occupier
47	2	sea	seasonal farmer
48	2	confarm	contract farmer
49	3	typefarm	type of farm (lfa sheep, beef, beef + sheep)
50	2	mxeww	keep max ewes for welfare reasons
51	2	mxewl	keep max ewes for labour reasons
52	2	mxewin	keep max ewes for infrastructure reasons
53	2	mxewwea	keep max ewes for weather reasons
54	2	mxewper	keep max ewes for performance reasons
55	2	mxeweeco	keep max ewes for economics reasons
56	2	mxewf	keep max ewes for forage reasons
57	2	mxewot	keep max ewes for others reasons
58	3	mxcaw	keep max cows for welfare reasons
59	3	mxcal	keep max cows for labour reasons
60	3	mxcain	keep max cows for infrastructure reasons
61	3	mxcawea	keep max cows for weather reasons
62	2	mxcaper	keep max cows for performance reasons
63	3	mxcaeco	keep max cows for economics reasons

64	3	mxcaf	keep max cows for forage reasons
65	3	mxcaot	keep max cows for others reasons
66	2	cwshe	work contractor do - shearing
67	2	cwga	work contractor do - gathering
68	2	cwsc	work contractor do - scanning
69	2	cwoth	work contractor do - others
70	2	hay	Produce hay self
71	2	chay	Use contrator for hay
72	2	nhay	No hay
73	2	sil	Produce silage self
74	2	csil	use contrator for silage
75	2	nsil	No silage
76	2	seag	Do you have seasonal grazing
77	2	fmsh	Have you got farm shop
78	2	tou	Tourist accommodation on farm
79	2	for	Forestry on farm
80	2	spr	Sporting activities on farm
81	2	phmst	Phone mast on farm
82	2	engy	Energy production on farm
83	2	othdiv	Other diversification on farm
84	2	rkfarm	Farming activity rank
85	3	calsprng	spring calving
86	3	calsum	summer calving
87	3	calautu	autumn calving
88	3	scan	Do you pregnancy scan
89	4	lambng	lambing time
90	2	cloflo	have you a closed flock
91	4	hqlty	Hill quality grazing
92	5	hqty	Hill quantity grazing
93	4	pkqlty	Park quality grazing
94	4	pkqty	Park quantity grazing
95	4	fieqlty	Fields quality grazing
96	5	fieqty	Fields quantity grazing
97	3	hayfieqlty	Fields for hay/silage quality grazing
98	4	hayfieqty	Fields for hay/silage quantity grazing
99	3	distissue	are distances on farm an issue?
100	2	health	do you have a health plan?
101	2	vets	Use of vets
102	5	comdisease	Most common disease in area
103	6	farmdisease	Biggest disease problem on farm
104	2	RSS	RSS
105	2	ESA	ESA
106	2	CPS	CPS
107	2	WGS	WGS
108	2	LMC	LMC
109	2	SFGS	SFGS
110	2	OAS	OAS
111	3	feedew	Feed ewes them in winter?
112	4	moti	what is your farming motivation?
113	2	buynewfl	Do you buy new stock
114	3	disrisk	If yes, disease risk
115	2	boudisea	Ever bought disease?
116	2	resothfarm	Use resources for other than farming
117	2	builincre	Are your buildings fit if animal numbers increase?
118	2	labincre	Have you enough labour to cope if animal numbers increase?
119	2	builfit	At present, are buildings fit for purpose?
120	2	builless	Are your buildings fit for other use if less animal numbers
121	2	otherless	Would you be prepared to do other if less animal numbers?
122	2	borrow	Would you borrow money for new venture?
123	2	buyunknow	Would you buy from unknown seller?
124	3	riskfarm	Risk attitude on your farm
125	4	sysfail	How often does your system fail?
126	3	bestqlty	I aim produce the best quality output on my farm
127	4	divers	I will try to diversify my income
128	4	fregardless	I intend to carry on farming regardless
129	5	profit	Profit making is my main motivation in farming
130	4	nxtgene	I will farm for the next generation to take over
131	3	effici	I will try to be more efficient/cost effective

132	2	impenvt	I will try to improve/maintain/care for the environment
133	5	lesssubs	I want to farm with less government subsidies
134	4	lessouts	I want to farm with less outside interference
135	4	qltytime	I would like to have more quality time for things other than farming
136	4	nofutu	There is no future in hill farming
137	4	nofutagr	There is no future unless there is more support from agri-environmental schemes
138	4	nofutincre	There is no future unless the prices increase substantially
139	4	diverway	Diversification is one way of making a better future
140	3	livgranec	Livestock grazing will be necessary to keep the hills suitable for hill walkers & tourists
141	3	stedecl	There will be a steady decline until the economic situation improves
142	4	farmcontr	Hill farmers are important contributor to the local economy
143	3	lessrurlab	There will be less rural labour without hill farming
144	3	respect	As a farmer, I am a respected member of the local community
145	3	badpress	Bad press has undermined farmers' standing in the local community
146	4	localunsym	Local residents are not sympathetic to farmers and their needs
147	4	localunderst	Local authorities do not understand farmers and their needs
148	4	profarming	Farmers should do more to promote farming interests
149	2	chgeneigh	Did your neighbours make any changes?

V.3. Variables in the further analysis (and post-clusters P values)

variable name	details	P value
age	age bracket	0.058
educ	level of education	0.051
yrsarea	years in in the area	0.072
succe	do you have a successor	0.455
chge01	any changes between 2001 & 2005?	0.24
ch01based	what were changes based on?	0.959
ch01pl	effect on paid labour from changes made in 2001-2005	0.03
ch01upl	effect on unpaid labour from changes made in 2001-2005	0.411
ch01h	effect on habitat from changes made in 2001-2005	0.677
ch01le	effect on local economy from changes made in 2001-2005	0.072
chge05	any changes since 2005?	0.669
ch05based	what were changes based on?	0.768
ch05pl	effect on paid labour from changes made since 2005	0.943
ch05upl	effect on unpaid labour from changes made since 2005	0.879
ch05h	effect on habitat from changes made since 2005	0.244
ch05le	effect on local economy from changes made since 2005	0.386
redliv01	reduction in livestock numbers between 2001 & 2005?	0.476
redliv05	reduction in livestock numbers since 2005?	0.945
resCAP	were these 2005 changes a result of the CAP reform?	0.685
postCap	how will your farming be post CAP reform?	0.932
Ltplan	do you have a long-term plan for your farm?	0.19
chgene05	were your neighbours' changes because of the SFP?	0.97
affect	will these changes affect your farm?	0.024

APPENDIX VI

Hill Grazing Management Model (HGMM) details, calculations and assumptions

VI.1. Overview

Details refer to the MLURI Hill Grazing Management Model, Ecological Manual, for Windows version 1.0. (1997).

The model was run for the 3 locations on Kirkton farm: the hill, the hillpark (i.e. fenced hill) and the inbye (pasture).

A series of inputs have to be entered in the model. They refer to:

- the site (zone, location, side of the country),
- the vegetation information (type of vegetation, altitude, area and cover, and, when required, management class and fertiliser)
- the grazing animals (sheep numbers per month and average weight in kg).

The model first calculates the production of each of the vegetation types in each month of the year, taking into account altitude and temperature zone. It then simulates the vegetation production and grazing by sheep from each vegetation type on each day of a typical year. The model runs for 2 years. By the second year, it has reached a steady state and will not be influenced by initial values.

The output file contains all the information entered into the input screens as well as a large number of outputs, in particular monthly output data. These monthly data are presented either as the total for each month or as the daily value on the last month (see next paragraph for full details). For this study, the total monthly production (kgDM/ha) of each vegetation type has been used, as well as the monthly digestibility of the vegetation type. Utilisation rate of the vegetation has also been applied, as explained in the next paragraphs.

VI.2. Inputs data

VI.2.1. Site data

VI.2.1.1. Zone

The zone is the temperature zone in which the site is located. The climatic zones are delineated on the basis of mean July temperature at sea level. Kirkton is situated in zone 4.

VI.2.1.2. Location

The model can predict vegetation of lowland areas, as well as upland and heath areas. Kirkton is located in the uplands.

VI.2.1.3. Side

The side of the country in which the site is located affects the default heather cover. If the site is in the east of the country, i.e. east of, or including, the Grampians in Scotland, or the Pennines in England, the default cover values are higher than if it is in the west of the country, where conditions tend to be wetter and heather grows less well. Kirkton is in the west side of the country.

VI. 2.2. Vegetation information: Heather

VI.2.2.1. Altitude

The average altitude (in metres) of all heather types must be entered. For Kirkton, two types of location were considered:

- Hill: Altitude: 400 m
- Hillpark: Altitude: 200 m

VI.2.2.2. Area and Cover

This is the area, in ha, of each of the seven heather types at the site (Newly burnt, Pioneer, Building, Mature, Degenerate, Suppressed, Blanket bog), as well as the average ground cover of heather within the total area of each of the seven aforementioned heather types.

For Kirkton, the values were as follows:

- Hill:
    a. Area of newly burnt heather: 1.74 ha
    b. Cover: 100%
- Hillpark:
    a. Area of newly burnt heather: 0.32 ha
    b. Cover: 100%

VI.2.3. Vegetation information: Indigenous grassland

VI.2.3.1. Altitude

The average altitude, in metres, of all indigenous grassland types must be provided. For Kirkton, as mentioned above, two types of location and altitude were considered.

VI.2.3.2. Grassland type

The grassland types, which can be simulated by the model, are defined as below:

- Agrostis/Festuca (species rich grassland dominated by *Agrostis* spp. and *Festuca* ssp., but with a higher proportion of *Agrostis* ssp),
- Festuca/Agrostis (species poor grassland dominated by *Festuca* spp. and *Agrostis* ssp. but with a higher proportion of *Festuca* spp.)
- Nardus (grassland with a higher proportion of *Nardus stricta* than any other grass types in the model)

- Burnt Molinia (grassland with a higher proportion of *Molinia caerulea* than any other grass types in the model and which has been burnt within the last year)
- Unburnt Molinia (as above but which has not been burnt within the last year).

It is assumed that *Nardus* is not eaten by sheep. However, the area of *Nardus* grassland was included in the model, as *Festuca/Agrostis* growing between *Nardus* tussocks can be a very important resource to sheep (Holland, 2001).

VI.2.3.3. Areas and cover

The area in ha, as well as the cover of each of the indigenous grassland types must be provided. The cover is the average ground cover within the appropriate grassland type of the grass types for which this is required (*Nardus* and *Molinia*). Cover is also required for species poor *Festuca/Agrostis* growing amongst each of the heather type and amongst *Nardus* and burnt and unburnt *Molinia*. The total cover of any two vegetation types growing in mosaic must not exceed 100%.

For Kirkton, the areas (in ha) and the cover (in %) taken were as follows:

- *Hill*
    a. Festuca/Agrostis: 11.17 ha, 100%
    b. Nardus: 681.74 ha, 32%
    c. Unburnt Molinia 156.84 ha 21.2%
    d. Festuca/Agrostis in Nardus 28.4 %
    e. Festuca/Agrostis in unburnt Molinia 2.4 %
- *Hillpark*
    a. Festuca/Agrostis: 6.42 ha, 100%
    b. Nardus: 29.34 ha, 41.6%
    c. Unburnt Molinina: 1.91 ha, 67%
    d. Festuca/Agrostis in Nardus: 19.25 %
    e. Festuca/Agrostis in unburnt Molinia 4.17 %

VI.2.4. Vegetation information: Reseeded Grassland

For Kirkton, the reseeded grassland is referred to as the Inbye land. Only parts of the total inbye area are fertilised.

VII.2.4.1. Altitude

For Kirkton, the average altitude of the reseeded grassland was 150 metres.

VII.2.4.2. Area, Management class and Fertiliser information

The area of reseeded grassland is provided below.

According to the model, the Management class is 1 if it is permanent grassland containing large amounts of clover. It is 2 if it is permanent grassland receiving less than 300 kg N/ha.

If fertiliser is applied, then the rate, in kg/ha/year must be supplied as well as the soil type and the average summer rainfall.

For Kirkton, the values taken were as follows:

- *Fertilised grassland*
    1. Pasture information:
        - Area: 34.5 ha (silage field)
        - Management class: 2
        - Fertiliser rate: 300 kg/ha/year
        - Soil type: 1 (all soils except shallow soils over chalk/rock or gravelly and coarse sandy soils or organic soils in the east of the country)
        - Rainfall: 1 (greater than 500 mm)
    2. Grassland information:

        Agrostis/Festuca: 47.5 ha, 100% cover
- *Unfertilised grassland*

    Agrostis/Festuca: 150 ha, 100% cover

VI.2.5. Sheep information

The model can predict the offtake by sheep, as well as the digestibility of the offtake. The model assumes that all sheep are ewes and produce one lamb each.
In the context of this study, the offtake by sheep is not required, as it is the vegetation information that is needed. However, for the model to provide the vegetation digestibility values, a number of animals must be entered. In this case, the minimum value of 1 sheep on the hill per month was entered, with an average typical live weight of 48.9 kg.

VI.3. Outputs data

VI.3.1 Heather data

For each heather vegetation type, the heather shoot biomass production (kg Dry Matter ha^{-1}), the amount eaten by the whole flock (offtake) from the most recent year's shoot biomass (kg Dry Matter ha^{-1}) and the standing biomass of the most recent year's shoot growth (kg Dry Matter ha^{-1}) were given as totals for each month.

VI.3.2 Grass data

For each vegetation type, the biomass production, offtake of green biomass and offtake of dead biomass (kg Dry Matter ha^{-1}) were given as totals for each month. Standing green biomass and standing dead biomass (kg Dry Matter ha^{-1}) were given for the last day of each month. *Festuca/Agrostis* growing in mosaic within each of the other vegetation types was considered separately.

VI.3.3. Sheep data

Ewe numbers on the hill in each month of the year, as input to the model by the user, were listed. A range of information was provided for an individual ewe, in relation to each of the vegetation type. They included in particular the digestibility of the diet, i.e. the proportion of the intake which can be digested.

VI.4. Utilisation rate and vegetation production on the hill

VI.4.1. Rationale

Which HGMM output value should be used to calculate the amount of energy from the hill/hillpark/inbye?

HGMM, in essence, looks at the impact of grazing on the vegetation. It requires therefore knowing how many animals are on a particular hill. HGMM predicts the utilisation rate of a vegetation type (i.e., the percentage of the annual production to date which has been removed by grazing). However, it is linked (but not linearly) to the number of animals grazing that particular vegetation. In the case of this PhD model, the question is reversed. The model tries to work out how many animals could be supported on that particular vegetation. On that premise, all the HGMM outputs relating to the number of animals cannot be used, since the number of grazing animals must be known in advance. Hence, the HGMM predictions of offtakes and utilisation rates are of no use.

The HGMM model also estimates vegetation production (kgDM/ha) and the green and dead biomass (kgDM/ha). The green and dead biomass shows the build up of biomass on that particular area, and is much higher than the production variable. In the case of this PhD's model, the "production" variable seems to be the most appropriate output to use, as, in essence, an animal cannot eat more than what is produced. However, on a hill, vegetation production differs from the amount of vegetation that can by physically ingested by the animal. Also, if an animal eats all the vegetation produced on month 1, then production of month 2 will be seriously reduced or non-existent. So, should the amount of energy provided by the vegetation be calculated using only the production values predicted by the HGMM?

On the inbye, the utilisation rate is near 100% (Holland, pers. comm.).To account for the issue of utilisation rate on the hill and hillpark, it was decided to use the production (kgDM/ha) value in the calculation of the energy available/produced on the hill/inbye/hillpark, but with the added constraint of a fixed maximum number of animals grazing on that particular area: **2700 ewes and 70 cows**.

By restricting the maximum number of animals on the farm during the year, the issue of utilisation rate of the vegetation can be circumvented. Using this approach, and assuming that **90%** of the energy produced by the inbye vegetation can be used, only **24%** of the total energy produced by the hill and hillpark vegetation is required to feed the maximum of the animals on that farm. This margin allows for the problem of overestimating the energy that is really available to the animals by using the production values.

VI.4.2. Details of calculations

The total amount of energy required by 2700 ewes and 70 cows is (from Appendix VII.):

Winter: 1.47*2700 + 16.67*70 = 5136 GJ

Spring: 1.53*2700 + 9.30*70 = 4782 GJ

Summer: 1.09 *2700 + 8.18*70 = 3516 GJ

Total = 13434 GJ

The total amount of energy supplied by the inbye vegetation, based on HGMM production values, is:

Winter: 174 ha* 4.61 = 802 GJ

Spring: 232 ha *24.62 = 5712 GJ

Summer: 232 ha * 20.59 = 4777 GJ

Total = 11291 GJ

This energy is available to the animals at 90% (90% utilisation rate) = 10162 GJ

The total amount of energy supplied by the hill & hillpark vegetation, based on HGMM production values, is:

Winter: 389 ha*1.06 + 1482 ha*0.15 = 635 GJ

Spring: 486 ha*5.26 + 1482 ha* 3.29 = 7432 GJ

Summer: 486 ha * 5.59 + 1482 ha * 1.85 = 5458 GJ

Total = 13525 GJ

Out of the 13434 GJ required by the animals, 10162 GJ can be supported by the inbye (at 90%). The rest, (13434-10162 = 3272), is supported by the hillpark & hill, with an utilisation rate of:

3272/13525 = 0.24

APPENDIX VII

Metabolisable Energy requirements, calculations and assumptions

VII.1. Overview

An animal has different energy requirements depending on its physiological stage - maintenance, gestational, lactating, growing. Different countries have different systems to calculate these requirements, based upon their husbandry systems or environments (e.g. SCA (1990) for Australia; Jarrige (1989) in France). In the UK, AFRC (1993) describes the Metabolisable Energy (ME) system, which is based upon the basic relationship between Metabolisable Energy (ME), intake from a feed or a diet, and the Net Energy (E) utilised or retained in the animal product, both expressed as MJ per day:

$$\mathbf{E = ME \times k}$$

where k is the efficiency of utilisation of ME for the relevant metabolic process.

In this study, the Net Energy is calculated for each physiological stage considered (maintenance Em, Gestation Ep, Lactation El, Growth Eg). Full details of the calculations are given in the next paragraph.

The total Metabolisable Energy for the ewe and the cow is an extension of the formula: ME=E/k

$$\mathbf{METotal = Em/km + Ep/kp + E_l/kl + Eg/kg}$$

The different efficiencies of utilisation of ME are defined by preferred linear equations involving qm, the ratio of ME to the gross energy (GE) of the feed or diet:

qm = ME feed / GE

A mean value of GE=18.8 MJ/kgDM is generally used for ruminant diet (AFRC, 1993, p2).

The Metabolisable Energy of the feed (ME feed) is given by the following equation:

ME feed (MJ/kgDM) = OMD x 0.157 x 100 (AFRC, 1993, p43)

OMD is the Organic Matter Digestibility (g/kg of a diet or feed):

OMD = (D-0.037)/0.94 (MAFF, 1975)

with D = digestibility of the diet

The digestibility of the diet D is provided by the HGMM model results, on a monthly basis, for the different vegetation types (or feed) in the three locations (hill, hillpark and inbye), as explained in Appendix VI.

VII.2. Net Energy calculation for the animals

VII.2.1. Net Energy for maintenance (Em)

The equation (defined by AFRC, 1993) is as follow:

Em (MJ/d) = (F + A)

where F is the fasting metabolism and A is the activity allowance. F and A vary according to the type of animals.

- Hill sheep (over 1 year old):

$F = C1 \times [0.23 \times (weight/1.08)^{0.75}]$

C1=1.15 for ram, 1.0 for female and castrates; A = 0.024 x weight

- Cattle:

$F = C1 \times [0.53 \times (weight/1.08)^{0.67}]$

C1 = 1.15 for bulls, 1.0 for other cattle, A = 0.0071 x weight

VII.2.2. Net Energy for pregnancy (Ep)

VII.2.2.1. Ewe

$$\mathbf{Ep\ (MJ/d) = 0.25 \times W_o \times [e^{(3.322-4.979 \times [exp(-0.00643 \times t)])} \times 0.07372 \times e^{(-0.00643 \times t)}]}$$

where W_o = total lamb weight at birth (in kg)

t = number of days since conception

VII.2.2.1. Cow

$$\mathbf{Ep\ (MJ/d) = 0.025 \times W_c \times [e^{(151.665-151.64 \times [exp(-0.0000546 \times t)])} \times 0.0201 \times e^{(-0.0000576 \times t)}]}$$

where W_c = calf birthweight (in kg)

t = number of days since conception

VII.2.3. Net Energy for lactation (E_l)

$$\mathbf{E_l\ (MJ/d) = Milk\ Yield\ (kg/d) \times Energy\ Value\ per\ litre\ of\ milk}$$

VII.2.3.1. Ewe

The Energy Value for milk ewe is 4.5 MJ/kg for Months 1-2 to 4.7 MJ/kg for Months 3-4. The milk yield depends on number of lambs and the month of lactation. For a hill lamb (AFRC, 1993, p97), the values are as follows:

Litter size	Month 1	Month 2	Month 3
1	1.25	1.05	0.70
2	1.90	1.60	1.10

VII.2.3.2. Cow

Energy value in cow milk (MJ/kg) = 0.0406 x BF + 1.509

where BF = butterfat content (g/kg) = 38

Milk Yield (kg/d) = $8.0 \times n^{0.121} \times e^{(-0.0048 \times n)}$ (Somerville et al. 1983)

where n=day of lactation

VII.2.4. Net Energy for growth (Eg)

Eg (MJ/d) = $\Delta W \times EVg$

VII.2.4.1. Sheep

Growing sheep (lamb) (AFRC, 1993, p28)

$EVg = 2.5 + 0.35xW$

where W is the liveweight (kg)

Ewe (AFRC, 1993, p32)

If $\Delta W > 0$, EVg = 23.85 MJ/kg

If $\Delta W < 0$, EVg = 23.85 x 0.84 = 20.03 MJ/kg

VII.2.4.2. Cow

Growing cattle (calf) (AFRC, 1993, p27)

$$\mathbf{EVg = C2 \times [4.1 + 0.0332 \times W - 0.000009 \times W^2] / (1 - 0.1475 \times \Delta W)}$$

where W is the liveweight (kg),

C2 = correction factor for mature body size and sex of the animal, C2 = 0.85 (assumed late castrates; AFRC, 1993, p28)

Cow (AFRC, 1993, p31)

If $\Delta W > 0$, EVg = 19 MJ/kg

If $\Delta W < 0$, EVg = 19 x 0.84 = 15.96 MJ/kg

VII.3. Metabolisable Energy calculations for the animals

VII.3.1. Efficiencies of utilisation of ME

VII.3.1.1. Maintenance

km = 0.35 x qm +0.503 = 0.019 x ME feed + 0.503

VII.3.1.2. Lactation

kl = 0.35 x qm +0.420 = 0.019 x ME feed + 0.420

VII.3.1.3. Growth

Growing ruminant

kf = 0.78 x qm + 0.006 = 0.041 x ME feed + 0.006

Lactating ruminant

kg = 0.95 x kl

VII.3.2. Animal Monthly calculations

VII.3.2.1.Ewe

For the hill ewe, the following assumptions were made:

Maintenance: all year round

Pregnancy: Dec-Jan-Feb-Mar-Apr

Lactation: May-Jun-Jul-Aug

Growth: all year round

Kirkton historic data were used (from a 2500 ewe flock) for data on weight change, ewe body weight and lamb birth weight.

Weight change:

Dec-Jan-Feb: -1.3 kg

Mar-Apr-May-Jun-Jul-Aug: 0.55 kg

Sep-Oct-Nov: 0.23 kg

Average ewe body weight (kg) = 45.82 kg

Single lamb weight = 4.1 kg

Twins lamb weight (combined) = 7.92 kg

VII.3.2.2. Cow

For the cattle, the following assumptions were made:

Maintenance: all year round

Pregnancy: Jun-Jul-Aug-Sep-Oct-Nov-Dec-Jan-Feb-Mar

Lactation: Mar-Apr-May-Jun-Jul-Aug-Sep-Oct-Nov

Growth: all year round

Data on weight change were taken from Petit et al., (1994) and from SAC upland farm near Edinburgh (for summer grazing).

Weight change:

Jan-Feb-Mar-Apr: -0.06 kg/d

May-Jun: 0.29 kg/d

Jul: 0.63 kg

Aug: -0.59 kg

Sep: 0.25 kg

Oct-Nov-Dec: 0.29 kg

Cow body weight (kg) = 550 kg

Calf body weight: (cow bodyweight$^{0.73}$-28.89)/2.064 = 30.5 kg

VII. 3.3. Total ME requirements

In this study, the ME requirements for each animal type (ewe, lamb, cow and calf), on the three types of diet available (hill, hillpark and inbye) were calculated on a monthly basis, by multiplying the equations' results by 30.

VII.4. Calculation of the total Metabolisable Energy provided by the diet

The HGMM model provides the digestibility of the diet (or vegetation) and the vegetation production per ha.

From these values, the monthly ME provided from the total digestible production can be calculated for the whole area of hill, hillpark or inbye.

It is therefore possible to obtain the ME provided by the diet in GJ/ha/month.

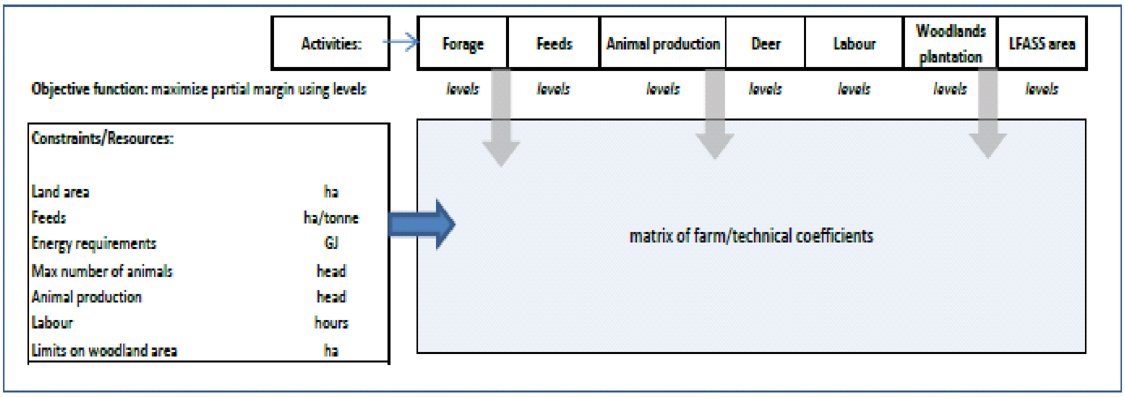
The table below shows the monthly values of the ME provided by the total digestible production for the three vegetation types (or diet).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hill	0.009	0.011	0.026	0.072	0.968	2.254	1.507	0.241	0.106	0.063	0.030	0.015
Hillpark	0.063	0.074	0.186	0.433	2.081	2.744	3.445	1.481	0.668	0.407	0.218	0.109
Inbye	0.272	0.323	0.818	2.448	10.637	11.535	11.121	6.287	3.179	1.785	0.940	0.470

APPENDIX VIII

Linear Programming variables, technical coefficients and other calculations

VIII.1. Schematic representation of the basic structure of the LP



VIII.2. List of LP activities

VIII.2.1. Forage

- Energy provided by the vegetation on the Hill (winter, spring, summer)
- Energy provided by the vegetation on the Hillpark (winter, spring, summer)
- Energy provided by the vegetation on the Inbye (winter, spring, summer)

VIII.2.2. Feeds

- Make silage (for winter feeds, for spring feeds)
- Sell silage (winter, spring)
- Purchase concentrates (winter, spring, as a supplement to forage)
- Purchase hay (winter, spring)

VIII.2.3. Livestock production (winter/spring/summer)

- Ewe:

i. maintain the ewe (winter, spring, summer)
ii. sell store lambs in summer
iii. sell fat lambs in summer, in winter
iv. keep replacement ewes (in summer)
v. buy replacement ewes (in summer)
vi. sell replacement ewes (in winter)
vii. sell draft ewes (in summer)
viii. sell wool (in summer)

- Cattle :

i. Maintain the cow (winter, spring, summer)
ii. Sell store calf (male and female) in summer
iii. Sell fat calf (male and female) in winter
iv. Purchase replacement heifer (in summer)
v. Sell old cow (cull) in summer

VIII.2.4. Deer

a. maintain deer on hill

VIII.2.5. Labour

a. Hire casual labour (winter, spring, summer)
b. Hire permanent labour
c. Pay overtime to the hired permanent labour

VIII.2.6. Forestry (native/commercial woodland)

a. Plant trees on hill
b. Plant trees on hillpark
c. Plant trees on inbye

VIII.2.7. LFASS (calculate the amount of land eligible for Less Favoured Area Support Scheme payment)

VIII.3. List of variables and coefficients

LAND	value	unit	notes
inbye land	232	ha	
hill park area	486	ha	
hill area	1482	ha	
inbye winter energy from 1 ha	4.61	GJ	from HGMM model (Appendix VI)
inbye spring energy from 1 ha	24.62	GJ	from HGMM model (Appendix VI)
inbye summer energy from 1 ha	20.59	GJ	from HGMM model (Appendix VI)
hillpark winter energy from 1 ha	1.06	GJ	from HGMM model (Appendix VI)
hillpark spring energy from 1 ha	5.26	GJ	from HGMM model (Appendix VI)
hillpark summer energy from 1 ha	5.59	GJ	from HGMM model (Appendix VI)
hill winter energy from 1 ha	0.15	GJ	from HGMM model (Appendix VI)
hill spring energy from 1 ha	3.29	GJ	from HGMM model (Appendix VI)
hill summer energy from 1 ha	1.85	GJ	from HGMM model (Appendix VI)
trashing effect on inbye during winter	25	%	estimated
trashing effect on hillpark during winter	20	%	estimated
min inbye area kept for grazing in summer	25	%	estimated
FEEDS	**value**	**unit**	**notes**
yield silage	20	tonne/ha	SAC FMH , 2010 (p110)
energy content from 1 tonne of silage	3.15	GJ	from HGMM model (Appendix VI)
energy content from 1 tonne of hay	6.89	GJ	from HGMM model (Appendix VI)
energy content from 1 tonne of conc winter (e+c)	11.00	GJ	averaged from SAC FMH (2010) p134 & p110
energy from 1 tonne of concentrates spring (e+c)	11.00	GJ	averaged from SAC FMH (2010) p134 & p110
amount of conc required with silage (as % silage)	7.4	%	from rations in SAC FMH (2010)
amount of conc required with hay (as % hay)	41.0	%	from rations in SAC FMH (2010)
ANIMAL PERFORMANCE	**value**	**unit**	**notes**
EWE			
ewe energy required in winter	1.43	GJ/ewe	over 6 months (Oct-Mar) - from AFRC equations (Appendix VII)
ewe energy required in spring	1.46	GJ/ewe	over 3 months (Apr-Jun) from AFRC equations (Appendix VII)
ewe energy required in summer	1.06	GJ/ewe	over 3 months (July-Sep) from AFRC equations (Appendix VII)
lamb energy required in summer (fattening)	0.23	GJ/lamb	1 month (S) from AFRC equations (Appendix VII)
lamb energy required in winter (fattening)	0.97	GJ/lamb	3 months (O,N, D) - from AFRC equations (Appendix VII)
ewe lamb energy required in winter (hogg fatten)	2.03	GJ/lamb	5 months (N,D,J,F,M) - from AFRC equations (Appendix VII)
ewe survival rate	0.92	ratio	from SAC FMH (2010) and from Morgan-Davies et al., 2008
lambing rate (at scanning)	1.22	ratio	SAC Kirkton data
% barren ewes	11	%	SAC Kirkton data
% twins ewes	33	%	SAC Kirkton data
lamb mortality	0.13	ratio	from SAC FMH (2010) and from Morgan-Davies et al., 2008
hogg survival rate	0.97	ratio	from SAC FMH (2010) p137
number of ewe crops	4		from SAC FMH (2010)
proportion female lamb kept for replacement	0.28	ratio	Calculated[1]
max number of ewes	2700		See Appendix VI.

COW			
cow energy required in winter	16.67	GJ/cow	over 6 months (Nov - Apr) from AFRC equations (Appendix VII)
cow energy required in spring	9.30	GJ/cow	over 3 months (May -Jul) from AFRC equations (Appendix VII)
cow energy required in summer	8.18	GJ/cow	over 3 months (Aug-Oct) from AFRC equations (Appendix VII)
calf energy required in winter (fattening)	7.11	GJ/calf	over 3 months (Nov-Jan) from AFRC equations (Appendix VII)
cow survival rate	0.99	ratio	from SAC FMH (2010) p 110
calving percentage	0.94	ratio	from SAC FMH (2010) p 110
calf mortality	0.045	ratio	from SAC FMH (2010) p 110
herd life of cows	7	years	from SAC FMH (2010) p 110
max number of cows	70		See Appendix VI.
DEER			
max deer density on hill	0.20	deer/ha	from Smart et al. (2008) and Kirkton data
MARKET	**value**	**unit**	**notes**
LAND & FEED			
cost of fertiliser	248	£/tonne	from Kirkton data
cost of lime	35.6	£/tonne	from Kirkton data
cost of fertiliser + lime on inbye	64.9	£/ha	From Kirkton data
cost of fert + lime on inbye (minus silage costs)	15.7	£/ha	From Kirkton data
cost of fertiliser on hillpark	0	£/ha	no fertiliser on hillpark
cost of fertiliser on hill	0	£/ha	no fertiliser on hill
cost of conserving silage (incl ferti+lime costs)	563.1	£/ha	From Kirkton data
cost of conserving silage	23.5	£/tonne	From Kirkton data
cost of conserving silage	445.0	£/ha	From Kirkton data
cost of purchasing silage	30	£/tonne	SAC FMH (2010) p 77
cost of purchasing hay	90	£/tonne	SAC FMH (2010) p 137
cost of winter concentrates (ewes + cows)	196.5	£/tonne	From Kirkton data
EWE			
cost of growing ewe	11.34	£/ewe	SAC FMH (2010) p137.
sheep veterinary & medicines	4.43	£/ewe	SAC FMH (2010) p137 - variable costs
sheep dips, commission, levies, haulage, shearing, scanning & tags	3.95	£/ewe	SAC FMH (2010) p137- variable costs
sheep scanning	0.65	£/ewe	SAC FMH (2010) p134- variable costs
ram replacement	4	£/ewe	SAC FMH (2010) p137
cost of growing ewe in winter	4.65	£/ewe	Includes ram costs (£4) and scanning (£0.65, SAC FMH (2010) p134).
cost of growing ewe in spring	4.43	£/ewe	Incl vet, medicine, dips
cost of growing ewe in summer	2.26	£/ewe	incl commission, levies, haulage, shearing, tags
amount of wool	1.6	kg/ewe	Kirkton data
value of wool	0.65	£/kg	SAC FMH (2010) p 137
price of fat lamb	62.35	£/hd	Incl extra dosing + straw (£1.95 +£2.7).
price of store lamb	39	£/hd	SAC FMH (2010) p137
price of store lamb sold later (1 month?)	53.05	£/hd	Incl. extra dosing (£1.95).
costs of ewe replacement (incl wintering) ie hoggs	18	£/hd	SAC FMH (2010) p137
price of selling replacement ewe lamb	65	£/hd	SAC FMH (2010) p139(ewe lamb production)
price of a gimmer	95	£/hd	SAC FMH (2010) p143
cost of buying hoggs	120	£/hd	SAC FMH (2010) p145 - more the gimmer price

price of draft ewe	42	£/hd	SAC FMH (2010) p137
COW			
cost of growing cow	145	£/cow	SAC FMH (2010) p111
cow vet & med	20	£/cow	SAC FMH (2010) p111
cow: haulage, commission & tags	31	£/cow	SAC FMH (2010) p111
cow: straw bedding	26	£/cow	SAC FMH (2010) p111
bull replacement	18	£/cow	SAC FMH (2010) p111
replacement cow	50	£/cow	SAC FMH (2010) p111
cost of growing cow in winter	127	£/cow	incl haulage, commission, tags vet & med, repl.
cost of growing cow in spring	18	£/cow	incl replacement bull (mating in June)
cost of growing cow in summer	0	£/cow	no variable costs for that period
price of store calf (male)	437.5	£/hd	SAC FMH (2010) p111
price of store calf (female)	374	£/hd	SAC FMH (2010) p111
price of fat calf (male)	612.5	£/hd	SAC FMH (2010) p111
price of fat calf (female)	544	£/hd	SAC FMH (2010) p111
SBCS	49.18	£/hd	SAC FMH (2010) p 107 (added to calf price in the LP)
price of cull cow	700	£/cow	SAC FMH (2010) p111
cost of purchasing heifer	1000	£/heifer	SAC FMH (2010) p111 (heifer in calf)
FORESTRY			
native woodland hill annualised income	109.8	£/ha	from NPV calc - reduced by 10% for hill
native woodland hillpark annualised income	122	£/ha	from NPV calc.
native woodland inbye annualised income	215	£/ha	from NPV calc.
com woodland hill annualised income	-7.7	£/ha	from NPV calc - reduced by 10% for hill
com woodland hillpark annualised income	-7	£/ha	from NPV calc.
com woodland inbye annualised income	86	£/ha	from NPV calc.
native woodland max benefits after 16 yrs	3503	£/ha	from NPV calc.
com woodland max benefits after 16 yrs	2356	£/ha	from NPV calc.
DEER			
cost of maintaining deer (labour costs)	6.48	£/deer	from Smart et al. (2008)
income from deer	18.53	£/deer	from Smart et al. (2008)

LABOUR	**value**	**unit**	**notes**
contractor cost	12	£/hour	from SAC FMH (2009)
contractor cost (spring - lambing)	15	£/hour	Kirkton data (& Ron Wilson, pers com)
shepherd wages	25000	£/yr	from SAC FMH (2009)
overtime rate	14	£/hour	Calculated[2]
number of existing farm employees	0	men	from Kirkton baseline data - can vary
limit on additional employees	3		Fixed
limit on casual in spring	5	men	Fixed
number of hours per year per FTE	1900	hours	SLR (Scottish Government, 2011a)
number of hours per FTE permanent in winter	720	hours	Calculated [3]
number of hours per FTE permanent in spring	590	hours	Calculated [4]
number of hours per FTE permanent in summer	590	hours	Calculated [4]
SLR beef cows	12	hour/hd /yr	SLR (Scottish Government, 2011a)
SLR other cattle	9	hour/hd /yr	SLR (Scottish Government, 2011a)
SLR calf kept for fattening	9	hour/hd /yr	assumed 9 hrs, as 9 hrs is for other cattle.

LABOUR NOT INCLUDING FEEDING:	value	unit	notes
number of hours for ewes in winter permanent only	0.072	hour/hd /yr	Kirkton data - 0.0022 pre-tup, 0.07 tupping
number of hours for ewes in winter casual only	0.03	hour/hd /yr	Kirkton data- 0.03 for scanning
number of hours for ewes in winter perm/casual	0.008	hour/hd /yr	Kirkton data – 0.008 for gathering (scanning+ pre-tupping)
number of hours for ewes in spring permanent only	0	hour/hd /yr	Kirkton data
number of hours for ewes in spring casual only	0	hour/hd /yr	Kirkton data
number of hours for ewes in spring perm/casual	0.544	hour/hd /yr	Kirkton data - 0.78+0.8 lambing, + 0.03 marking + 0.004 gathering for marking
number of hours for ewes in summer permanent only	0.05	hour/hd /yr	Kirkton data: 0.02 for weaning + 0.03 for dipping
number of hours for ewes in summer casual only	0	hour/hd /yr	Kirkton data
number of hours for ewes in summer perm/casual	0.018	hour/hd /yr	Kirkton data, 0.01 for shearing, +0.004 for gathering (x2)
number of hours for store lambs in summer permanent only	0.05	hour/hd /yr	Kirkton data: 0.03 for marking + 0.02 for weaning
number of hours for store lambs in summer perm/casual	0.008	hour/hd /yr	Kirkton data: 2 gathering (0.004*2)
number of hours for fat lambs in summer permanent only	0.075	hour/hd /yr	Kirkton data: 0.03 marking + 0.02 weaning + more feeding
number of hours for fat lambs in summer perm/casual	0.008	hour/hd /yr	Kirkton data: 2 gathering (0.004*2)
number of hours for hoggs in summer permanent only	0.11	hour/hd /yr	Kirkton data - 0.06 for taking hoggs out at marking, 0.05 for dipping
number of hours for hoggs in summer perm/casual	0.014	hour/hd /yr	Kirkton data, 0.01 for shearing, + 1 gathering 0.004
number of hours for lambs/hoggs sold in winter (permanent only)	0.02	hour/hd /yr	Kirkton data, haulage of hoggs = 0.02 hr
number of hours for cows in winter minus feeding (cas/perm)	4	hour/hd /yr	based on SLR (12 hours/hd/yr) [5] sales + calving (2hrs + 2hrs)
number of hours for cows in winter minus feeding (perm)	3	hour/hd /yr	based on SLR (12 hours/hd/yr) [5]. weaning + checking (2 hrs + 1 hr)
number of hours for cows in spring (perm)	2	hour/hd /yr	spring = only mating [6]
number of hours for cows in summer (perm)	1	hour/hd /yr	summer: only checking [6]
number of hours for cast animals (perm/casual)	0.0075	hour/hd /yr	Kirkton data - loading ewes = 0.01 hr/ewe Assumed same time for cast cows.
SLR other cattle minus feeding labour (perm)	6.75	hour/hd /yr	Assumed 4 major operations in 9 SLR minus feeding (3/4*9)
SLR growing beef calf (perm)	2	hour/hd /yr	from SAC FMH (2010) p216
annual number of hours per deer	0.0005	hours/ deer/yr	Smart et al. 2008: 1 deer needs 0.00054 stalker but shooting season is sept/oct

LABOUR RELATED TO FEEDING	value	unit	notes
number of hours per hectare to conserve silage	0.5195	hour/ tonne/yr	Kirkton data
SLR hill in winter (permanent labour)	0.0029	hour/ha/ for 6 m winter period	used Kirkton data, 0.0029/ewe - latest figures
SLR hill park grazing in winter (permanent labour)	0.0005	hour/ha/ for 6 m winter period	Kirkton data, 0.000499/ewe - latest figures Meall
SLR inbye winter (nearer steading)	0.0043	hour/ha/ for 6 m winter period	Kirkton data, used 0.0043/ewe - latest figures Horsepark
SLR inbye spring (nearer steading)	0.0040	hour/ha/ for 3 m spring period	Kirkton data - once a week (4 days total) – 0.7 hour/day (2 round trips of 20 min each)
SLR hillpark spring (bloc)	0.0027	hour/ha/ for 3 m spring period	Kirkton data - 1 month feeding once a week (4 days total) - 1 hour/day (1 round trip)
SLR hill spring (bloc)	0.0009	hour/ha/ for 3 m spring period	Kirkton data - 1 month feeding once a week (4 days total) - 1 hour/day (1 round trip)
SLR for feeding 1 tonne of silage	0.5000	hour/ tonne	from Kirkton[7]
SLR for feeding 1 tonne of hay	0.5000	hour/ tonne	from Kirkton[7]
SLR for feeding 1 tonne of concentrates (pellets from bag)	1.7	hour/ tonne	from Kirkton[8]

[1] *if number of ewe crops = n, then replacement rate = 1/[hogg survival rate+ ewe survival rate + …+ (ewe survival rate)$^{n-1}$]*

[2] *overtime rate = [full annual wages (£25000)/yearly SLR (1900 hrs) + 1]*

[3] *number of hours per FTE in winter (based on 4 hrs/day due to light) = 4 hours x 30 days x 6 months = 720 hours*

[4] *in spring/summer, number of hours per FTE equal (1900 – 720) = 1180 hours; over two periods of 3 months = 1180/2=590 hours per period*

[5] *calculation of SLR for cow per month/per period: assumed 6 major operations in 1 year (sales, weaning, calving, mating, winter feeding, checking). Each major operation occurs once in 1 year, except checking, which is during the year. To simplify, each operation has been assumed to be 2 hours (12/6) per year. For the checking operation, this equates to 0.17 hour per month (2/12). In winter (6 months), the operations are: sales, weaning, calving, winter feeding and checking = 2+2+2+2+(0.17*6) = 9 hours.*

[6] *In spring, the cow operations should be mating and checking (2+(0.17*3)=2.5 hours). However, due to the busy workload at this time of year, it was assumed that no checking would take place in spring. The SLR for that period is therefore only 2 hours. Conversely, the SLR for cows in summer has been increased to 1 hour (instead of 0.5 hours (0.17*3)).*

[7] *2 bales of silage/hay (~1 tonne) spiked by tractor, put on trailer and taken to field/shed*

[8] 2.5 min to empty 25 kg bag of pellets -> 10 min per 100 kg -> 100 min (1.7 hr) for 1 tonne/ take conc on bike (4 bags per trip - 100 kg per trip) then 20min round trips on average - total=200 min on bike . If only feeding (not driving since included in SLR of various locations, then only 100 min (1.7 hrs)/tonne.

VIII.4. Calculation of SFP/LFASS

VIII.4.1. Single Farm Payment

The amount of Single Farm Payment is based on historic payments for the reference period (2000-2002). All subsidies are based on prices from SAC Farm Management Handbook for 2002/2003.

For the sheep, this includes the Sheep Annual Premium (£12.62) and the LFA supplement (£4.21):

2689 breeding ewes @ £12.62 + 2689 breeding ewes @ £4.21 = £45,256

748 hoggs @ £12.62 + 728 hoggs @ £4.21 = £12,597

For the cattle, this includes the Suckler Cow Premium (£120.17) and the Extensification Premium (£48.07):

66 cow @£120.17 + 66 cows @£48.07 = £11,104.

The total SFP for Kirkton is = £45,256 + £12,597 + £11,104 = **£68,957.**

Note: the extensification premium requires a maximum stocking density of 1.4 LU per hectare. The LU for Kirkton are: 2689*0.15 + 748*0.15 + 66 (cows) + 57 *0.6 (calves) = 403+112+66+34 = 616 LU. The forage area is 2200 ha. The stocking density is: 616/2200 = 0.28, which is inferior to 1.4 LU.

VIII.4.2. The Less Favoured Area Support Scheme (LFASS) payment

It is linked to the LP results. The LP provides the number of hectares not used by forestry (therefore eligible for LFASS payment) and the number of animals on the farm. One sheep is the equivalent of 0.15 livestock unit (LU), whilst one cow is equivalent to 1 LU. The following calculations are based on the LFASS rules 2007-2009 (Scottish Government, 2007):

- Grazing category: Kirkton is in the fixed Grazing Category A, which gives each real hectare of the farm an adjusted value of 0.167 ha.
- If the farm has a mixed stocking regime, it receives an hectare uplift of 1.35 if at least 10% but less than 50% of the LU are cattle, and of 1.7 if 50% or more of the LU are cattle.
- There are minimum and maximum stocking density restrictions (0.12 LU/ha and 1.4 LU/ha respectively) for each eligible hectare.
- The final LFASS payment is also based on the parish area where the farm lies, with fragility markers in place for more remote areas. Kirkton lies in the parish of Killin, which is a standard area. Given the grazing category and the parish, the final payment rate is £37.80/adjusted hectare.

VIII.5. Calculation of the Net Present Values for Forestry

To calculate the Net Present Value of forestry, costs and benefits for each year are required, to calculate a net cash flow. A discounted cash flow is then calculated, by multiplying the net cash flow for each year by an appropriate discount factor, based on an interest rate of 7.6% in this case (average between Nationwide Building Society and Clydesdale Bank, October 2011).

The formula to calculate the discount factor is:

$$\mathbf{1/[1+(7.6/100)]^n}$$

where n is the year under consideration (SAC FMH (2010), p289)

The sum of the discounted cash flows is the Net Present Value for the whole time period and when this is divided by the number of years then this results in a single annualised value which is a reasonable approximation of average net benefits and which can subsequently be used in annual budgets, and more importantly in this case provides a value for the optimisation process.

For the first 5 years of forestry, the benefits encompass the initial planting grants (year 1), the maintenance grant (years 1 to 5), the fencing payment (year 1) and the Farmland Premium (years 1 to 5).

For the subsequent 10 years (year 6 to 15), the benefits encompass the Farmland Premium (years 6 to 15).

From year 16 there are no more support benefits and since thinnings and final harvesting are much further into the future, then it was deemed appropriate to base the annualised values on this first 16 year period.

The total costs for the first year are the planting costs (mounding and ground preparation, drainage, vole guard, weed control, laying out trees), the tree costs (£/tree), labour costs (planting, fertilising, management and supervision), fencing costs and maintenance costs (tree monitoring and deer monitoring and control). The second year only encompasses yearly maintenance costs (tree monitoring, deer monitoring and control, deer fence (0.25% of fencing costs)). In year 3, the beating up costs (10% of initial costs) need to be added to these yearly maintenance costs. For year 4 onwards, only the yearly maintenance costs are taken into account.

VIII.5.1. Native Woodland

Below is the NPV after 16 years for the native woodland (based on density = 1600 tree/ha with 25% open spaces => 1200 tree/ha).

Costs=

Planting costs = £546/ha

Tree costs = £348/ha

Labour costs = £540/ha

Fencing costs (8 gates, 10 km fence)= £250/ha

Maintenance costs = £2/ha

Deer fence maintenance costs = £0.625/ha

Beating up costs = £143/ha

Benefits=

initial grant = £2241.60/ha

maintenance grant = £218/ha

fencing payment = £172/ha

Farmland premium:

hill = £60/ha

inbye = £230/ha

VIII.5.1.1. Net Present Value, without the Farmland premium

Native Woodland HILL & INBYE (based on / ha)

Years	costs	benefits	net cash flow	discounted cash flow	discount factor
1	1686	2631	945	878.18	0.9294
2	2.63	218	215	186.02	0.8637
3	146.03	218	72	57.77	0.8027
4	2.63	218	215	160.67	0.7460
5	2.63	218	215	149.32	0.6933
6	2.63	0	-3	-1.69	0.6444
7	2.63	0	-3	-1.57	0.5988
8	2.63	0	-3	-1.46	0.5565
9	2.63	0	-3	-1.36	0.5172
10	2.63	0	-3	-1.26	0.4807
11	2.63	0	-3	-1.17	0.4468
12	2.63	0	-3	-1.09	0.4152
13	2.63	0	-3	-1.01	0.3859
14	2.63	0	-3	-0.94	0.3586
15	2.63	0	-3	-0.88	0.3333
16	2.63	0	-3	-0.813	0.3097
total after 16 years	1869	3503	1634	1419	
per year (/16)	117	219	102	**89**	

NPV after 16 years is £89/ha; £3503/ha is the total amount of grant given after 16 years.

VIII.5.1.2. Net Present Value, with only the Farmland premium

Native Woodland HILL (based on / ha)						Native Woodland INBYE				
Years	costs	benefits	net cash flow	discounted cash flow	discount factor	costs	benefits	net cash flow	discounted cash flow	discount factor
1	0	60	60	55.76	0.9294	0	230	230	213.75	0.9294
2	0.00	60	60	51.82	0.8637	0.00	230	230	198.66	0.8637
3	0.00	60	60	48.16	0.8027	0.00	230	230	184.63	0.8027
4	0.00	60	60	44.76	0.7460	0.00	230	230	171.58	0.7460
5	0.00	60	60	41.60	0.6933	0.00	230	230	159.47	0.6933
6	0.00	60	60	38.66	0.6444	0.00	230	230	148.20	0.6444
7	0.00	60	60	35.93	0.5988	0.00	230	230	137.73	0.5988
8	0.00	60	60	33.39	0.5565	0.00	230	230	128.01	0.5565
9	0.00	60	60	31.03	0.5172	0.00	230	230	118.96	0.5172
10	0.00	60	60	28.84	0.4807	0.00	230	230	110.56	0.4807
11	0.00	60	60	26.81	0.4468	0.00	230	230	102.75	0.4468
12	0.00	60	60	24.91	0.4152	0.00	230	230	95.49	0.4152
13	0.00	60	60	23.15	0.3859	0.00	230	230	88.75	0.3859
14	0.00	60	60	21.52	0.3586	0.00	230	230	82.48	0.3586
15	0.00	60	60	20.00	0.3333	0.00	230	230	76.66	0.3333
16	0.00	0	0	0.000	0.3097	0.00	0	0	0.000	0.3097
total after 16 years	0	900	900	526		0	3450	3450	2018	
per year (/16)	0	56	56	**33**		0	216	216	**126**	

NPV for native woodland on the hill after 16 years is £33/ha, and £126/ha for the inbye.
The total NPV is: £122/ha for native woodland on the hill and £215/ha for the inbye.

VIII.5.2. Conifer Woodland

For conifer woodland, the approach is similar. The woodland grant is: £1379.10/ha, the maintenance grant is £161/ha. The farmland premium is the same (£60/ha for the hill, £230/ha for inbye). Costs are based on a density of 2180 tree/ha (85% @ 2500, 3% @ 1100, 2% @1100, 10% open spaces).
The NPV after 16 years, when considering only the woodland grant, is -£40/ha. The total amount of grant received after 16 years is £2356/ha.
The total NPV for conifer woodland are: -£7/ha for the hill and £86/ha for the inbye.

VIII.6. Details of the LP framework

		Forage			Feeds					Winter animal production				Spring animal production		Summer animal production						
Activities		inbye	hillpark	hill	silage production for own use	silage production for sale	animal feed ration	buy concen trates	buy hay	maintain ewes	sell lambs	maintain cow	sell calves	maintain ewe	maintain cow	maintain ewe	sell lambs	keep replace ment ewes	sell draft ewes	maintain cow	sell calves	sell draft cow
Objective function		costs £/ha	costs £/ha	costs £/ha	costs £/ha	revenue £/ha	tonne	costs £/t	costs £/t	costs £/head	revenue £/head	costs £/head	revenue £/head	costs £/head	costs £/head	costs £/head	revenue £/head	revenue £/head	revenue £/head	costs £/head	revenue £/head	revenue £/head
Constraints																						
max inbye area	≤ available hectares	1			+aij	+aij																
max hillpark area	≤ available hectares		1																			
max hill area	≤ available hectares			1																		
silage	≤0				-aij	-aij	+aij															
concentrates	≤0						-aij	-1														
energy requirements in winter	≤0	-aij	-aij	-aij	-aij			-aij	-aij	+aij	+aij	+aij	+aij									
energy requirements in spring	≤0	-aij	-aij	-aij	-aij			-aij	-aij					+aij	+aij							
energy requirements in summer	≤0	-aij	-aij	-aij												+aij	+aij	+aij		+aij		
max number of ewes	≤ fixed maximum number									1												
ewe production	≤0									-1				1		1						
lamb production	≤0										+aij					-aij	+aij					
female lamb production	≤0															-aij		+aij				
draft ewes production	≤0															-aij			1			
max number of cows	≤ fixed maximum number											1										
cow production	≤0											-1			1					1		
calf production	≤0																			-aij	+aij	
cull cow production	≤0																			-aij		+aij
heifer replacement	≤0																					
labour	≤ available labour in hours	+aij	+aij	+aij	+aij	+aij		+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij	+aij

Details of LP framework (continued)

Activities		**Game**	**Labour**		**Woodland plantation**					**LFASS**
		provide game for shooting	hire casual labour	hire another permanent labour	native on hill	native on inbye	commercial on hill	commercial on inbye	total area planted	LFASS area
Objective function		costs £/head	costs £/hour	costs £/person	revenue £/ha	revenue £/ha	revenue £/ha	revenue £/ha	ha	ha
Constraints										
max inbye area	≤ available hectares					1		1		
max hillpark area	≤ available hectares				1		1			
max hill area	≤ available hectares	+aij			1		1			
silage	≤0									
concentrates	≤0									
energy requirements in winter	≤0									
energy requirements in spring	≤0									
energy requirements in summer	≤0									
max number of ewes	≤ fixed maximum number									
ewe production	≤0									
lamb production	≤0									
female lamb production	≤0									
draft ewes production	≤0									
max number of cows	≤ fixed maximum number									
cow production	≤0									
calf production	≤0									
cull cow production	≤0									
heifer replacement	≤0									
labour	≤ available labour in hours	+aij	-1	-aij						
limit on additional permanent labour	≤ number of men			1						
limit on casual hired labour	< available labour in hours		1							
limit on hill plantation	≤ hill area + hillpark area				1		1			
limit on inbye plantation	≤ inbye area					1		1		
total area planted	≤ 0				-1	-1	-1	-1	1	
total farm land	≤ max available area								-1	1

VIII.7. Details of technical coefficients (other than 1 and direct variables)

VIII.7.1. Forage:

- Provide energy from the inbye in winter vs. Maximum area for grazing the inbye in winter = 1.3 = 1/[1-(trashing effect on inbye in winter/100)]
- Provide energy from the hillpark in winter vs. Maximum area for grazing the hillpark in winter = 1.25 = 1/[1-(trashing effect on hillpark in winter/100)]

VIII.7.2. Feeds:

- Make silage vs. Maximum area for grazing the inbye in summer = 0.75 = 1-(minimum inbye area kept for summer grazing/100). Some of the hectares used by the silage making are always kept for grazing.
- Make silage vs. energy content = silage yield x energy content in 1 tonne of silage
- Make silage vs. labour available in summer = [hrs/ha to conserve the silage + SLR for feeding 1 tonne of silage] x silage yield.
- Sell silage vs. Maximum area for grazing the inbye in summer = 0.75 = 1-(minimum inbye area kept for summer grazing/100). Some of the hectares used by the silage making are always kept for grazing.
- Sell silage vs. energy content = silage yield x energy content in 1 tonne of silage
- Sell silage vs. labour available in summer = [hrs/ha to conserve the silage] x silage yield.
- Supplementation for sheep/cow (ration) vs. silage (*warehouse*) = [1- % of concentrates required with silage]
- Supplementation for sheep/cow (ration) vs. concentrates = [1- above]]

VIII.7.3. Livestock winter activities:

- Maintain ewe unit in winter vs. labour available in winter = Σ (number of hours for ewes in winter)

- Sell fat lambs in winter vs. supply lambs for sale = [1/(1-lamb mortality)]+[0.01 (additional mortality from weaning to selling)]
- Sell fat lambs in winter vs. labour available in summer = Σ (number of hours for fat lambs in summer)
- Maintain cow unit in winter vs. labour available in winter = Σ (number of hours for cows in winter)
- Sell fat calf (male & female) later vs. supply store calf (female & male) for sale = [1/(1-calf mortality)]+[0.01 (additional mortality from weaning to selling)]
- Sell fat calf (male & female) later vs. labour available in winter;
  - store calf is sold at 7 months, which costs 4 hrs of SLR. A fat calf costs 9 hrs of SLR, and is sold at 10 months. Store calf is sold 1 month within winter period, whilst the fat calf is kept for 3 months longer.
  - Per period, the store calf requires [4 hrs/7 months] x 3 months for summer and spring, and [4 hrs/7 months] x 1 month for winter. The fat calf requires similar hours for summer and spring, but needs an additional time in winter (corresponding to the 3 months) = [(9 hrs SLR – 4 hrs SLR)/10 months] x 3 months.
  - Technical coefficient is therefore: [SLR beef calf/7] + [(SLR fattening – SLR beef calf)/ 10] x 3.
- Sell fat calf (male & female) later vs. labour available in spring and summer = [(SLR beef calf/7) x 3] (see above explanation)

VIII.7.4. Livestock spring activities:

- Maintain ewe unit in spring vs. labour available in spring = Σ (number of hours for ewes in spring)

VIII.7.5. Livestock summer activities:

- Maintain ewe unit in summer vs. supply lambs for sale = (ewe survival rate x lambing rate) – replacement rate

- Maintain ewe unit in summer vs. supply draft ewes =

  [ewe survival rate$^{(n-1)}$]/[hogg survival rate + ewe survival rate + ewe survival rate^2 + …+ ewe survival rate$^{(n-1)}$], with n=number of ewe crops

- Maintain ewe unit in summer vs. labour available in summer = Σ (number of hours for ewes in summer)
- Sell fat lamb on grass vs. supply lamb for sale = 1/(1-lamb mortality)
- Sell fat lamb on grass vs. labour available in summer = Σ (number of hours for lambs in summer)
- Sell store lamb vs. supply lamb for sale = 1/(1-lamb mortality)
- Sell store lamb vs. labour available in summer = Σ (number of hours for lambs in summer)
- Keep replacement ewe lamb vs. labour available in summer = Σ (number of hours for hoggs in summer)
- Maintain cow unit in summer vs. supply male (or female) store calf for sale = cow survival rate x calving percentage/2
- Maintain cow unit in summer vs. supply cull cow = 1/(herd life of cows)
- Sell (female & male) store calf vs. supply (male & female) store calf for sale = 1/(1-calf mortality)
- Sell (female & male) store calf vs. labour available in winter (see explanations in sell fat calf later section above) = [(SLR beef calf/7)]
- Sell (female & male) store calf vs. labour available in summer and spring (see explanations in sell fat calf later section above) = [(SLR beef calf/7) x 3]
- Sell old cow (cull) vs. supply cull cow = 1 + (cow mortality rate x herd life of cows)

VIII.7.6. Deer:

- Maintain deer for shooting vs. max are hill winter (spring/summer) = 1/max deer density on hill

VIII.7.7. Labour:

- Hire casual labour in winter vs. labour available in winter = 1 -0.1 -0.1. This reduction of coefficient for the casual labour is to represent the fact that casual labour does not necessarily know the farm as well as the permanent labour and might waste time (hence the -0.1). Also, in winter, the casual labour is not specialist labour (only feeding or other non-specialist husbandry work), hence the other reduction (-0.1).
- Hire casual labour in spring vs. labour available in spring = 1-0.1. This reduction of coefficient for the casual labour is to represent the fact that casual labour does not necessarily know the farm as well as the permanent labour and might waste time (hence the -0.1)
- Hire casual labour in summer vs. labour available = 1-0.1-0.1 (same as hire casual labour in winter).
- Hire another permanent labour vs. supply overtime for spring = 20% more than normal hours = 0.2 x 590 hours = 118 hours.

Final note: the "Woods total area planted" contribution is not a straightforward multiplication, it is as follow: [Σ area native woodland planted x native woodland maximum benefits after 16 years] + [Σ area commercial woodland planted x commercial woodland maximum benefits after 16 years]. The obtained value is not included in the objective function calculation, but is included in the constraints of the LP solver.

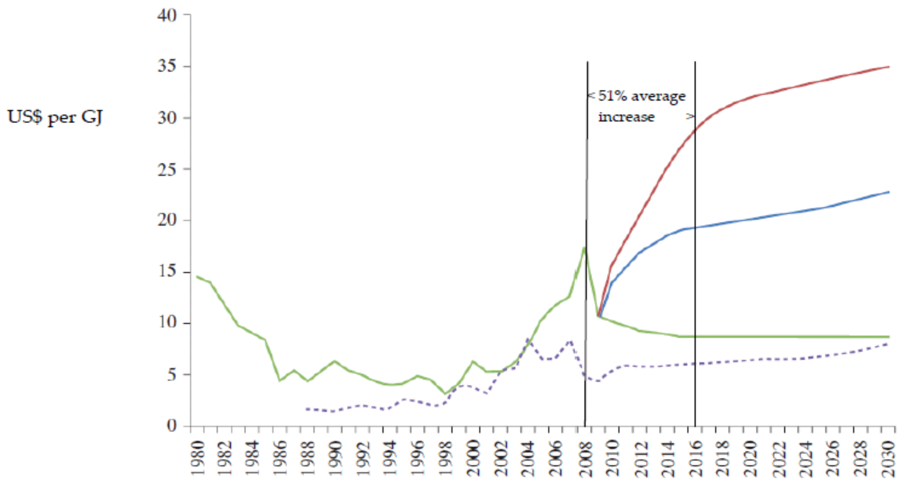
VIII.8. Summary of the Farm Business Income calculations

(in relation to the LP maximisation and the subsequent additions)

Farm Business Income					***How is it determined?***
= Farm Net Margin	**= Gross Margin**	**=Net Output**	**= Gross Output**	= Sheep output	LP activities
				+ Cattle output	LP activities
				+ Forage output	LP activities
			***minus* Replacements**	= Ewe replacement costs	LP activities
				+ Cow replacement costs	LP activities
				+ Ram replacement costs	Included in LP ewe variable costs
				+ Bull replacement costs	Included in LP cow variable costs
		***minus* Variable Costs**	**= Feed costs**	= Silage costs	LP activities
				+ Hay costs	LP activities
				+ Concentrates costs	LP activities
			+ Ewe costs	=Veterinary, bedding, haulage, market costs, tags, scanning, shearing	LP activities
			+ Cow costs	= Veterinary, bedding, haulage, market costs, tags	LP activities
	***minus* Fixed Costs**	**= Labour**	**= Casual**		LP activity
			+ Permanent		LP activity
		+ Machinery costs	= Fuel and maintenance		Added after LP maximisation
		+ Machinery depreciation			Added after the LP maximisation
		+ Land and buildings costs	includes rent and imputed rent		Added after the LP maximisation
+ Sub--sidies	**= SFP**				Added after LP maximisation
	+ LFASS				Calculated partly using LP activities (number of livestock and eligible area) and added after LP maximisation
+ Diversification income	**= Forestry income**				LP activity

VIII.9. Projected oil and gas price ranges (for scenario HF&E)

This figure is adapted from Woods et al. (2010) and shows the different projected oil and gas price ranges (in US$ per GJ) to 2030. For this study, two points on this graph are considered: 2008 and 2016. The 51% is the average of the fluctuation prices between these two points/dates.



Projected oil and gas price ranges to 2030; US$ per GJ. Source: US EIA (2009). Dark blue line, reference case ($130 per bbl oil); red line, high price ($200 per bbl oil); green line, low price ($50 per bbl oil); dashed violet line, gas: 2008 US$ GJ.

Adapted from Woods et al. (2010)

APPENDIX IX

Additional results from the optimisation model

IX.I. Comparison between the model parameterisation results and QMS/Scottish Government FAS data.

IX.I.1. QMS(2011) figures

QMS LFA hill suckler herds

	£/cow		
	bottom	***average***	***top third***
calf output	£445.06	£508.46	£582.68
subsidies	£39.66	£42.21	£45.81
replacement costs	£37.47	£40.60	£40.77
Net Output	**£447.25**	**£510.07**	**£587.72**
Variable Costs:			
feed & forage	£236.06	£201.55	£152.74
veterinary	£57.05	£49.27	£39.09
bedding	£25.37	£31.46	£32.91
other costs	£30.09	£22.45	£29.45
Gross Margin	**£98.68**	**£205.34**	**£333.53**
Fixed costs:			
labour	£123.26	£121.78	£120.27
other fixed costs	£225.98	£270.87	£310.61
Net Margin	**-£250.56**	**-£187.31**	**-£97.35**

QMS LFA hill breeding flocks

	£/ewe		
	bottom	***average***	***top third***
lambs sales	£32.77	£59.28	£78.32
wool	£0.60	£1.05	£1.08
replacement costs	£10.21	£9.84	£8.84
Net Output	**£23.16**	**£50.49**	**£70.56**
Variable Costs:			
feed & forage	£4.73	£9.20	£10.42
veterinary	£4.46	£4.81	£5.81
bedding	£0.09	£0.15	£0.29
other costs	£8.72	£7.52	£5.00
Gross Margin	**£5.16**	**£28.81**	**£49.04**
Fixed costs:			
labour	£9.40	£12.37	£12.30
other fixed costs	£19.88	£22.76	£28.06
Net Margin	**-£24.12**	**-£6.32**	**£8.68**

	QMS scaled up to 66 cows & 2689 ewes			
	bottom	***average***	***top third***	***Historic Baseline***
outputs (calf + lamb)	£120,110	£195,748	£252,083	£171,632
wool	£1,613	£2,823	£2,904	£2,797
replacement costs	£29,928	£29,139	£26,462	£23,199
Net Output	**£91,796**	**£169,432**	**£228,525**	**£151,230**
Variable Costs:		VC		
Feed & Forage	£28,299	£38,041	£38,100	£51,721
Other Variable costs	£43,109	£40,369	£36,544	£40,063
Gross Margin	**£20,388**	**£91,023**	**£153,882**	**£59,446**
Fixed costs				
labour	£33,412	£41,300	£41,013	£51,687
other fixed costs	£68,372	£79,079	£95,954	£41,267
Net Margin	**-£81,396**	**-£29,357**	**£16,915**	**-£33,508**

IX.I.2. Scottish Government (2011a) figures

	Large LFA sheep	Average LFA sheep + cattle	Large LFA sheep & cattle
no ewes	1078	616	956
no cows	15	63	93
outputs cattle	£6,842	£42,068	£64,681
outputs sheep	£45,266	£43,330	£68,713
Inputs:			
feeds	£17,051	£25,164	£40,079
other livestock costs	£12,266	£12,917	£19,600
labour	£10,702	£9,035	£17,008

		Scaled up from		
	Historic Baseline	Large LFA sheep	Average LFA sheep & cattle	Large LFA sheep & cattle
no ewes	2689	2689	2689	2689
no cows	66	66	66	66
outputs cattle	£33,193	£30,105	£44,071	£45,903
outputs sheep	£118,037	£112,913	£189,147	£193,273
Inputs:				
feeds	£51,721	£42,979	£102,101	£105,260
other livestock costs	£40,063	£30,918	£52,410	£51,476
labour	£51,687	£26,975	£36,659	£44,668

IX.2. Net Margin results for all profiles and all scenarios

IX.2.1. Standard Case Scenarios

	Standard case		W/B		AoH		NSa		NSa_priceinc		NSb		NSc		NSd	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	715	37,922	337	17,870	243	12,871	713	37,838	1,968	169,086	713	37,838	340	18,032	1968	169,086
draft ewe sales	217	9,124	102	4,299	74	3,097	217	9,103	598	70,339	217	9,103	103	4,338	598	70,339
wool sales (kg)	1569	1,020	739	481	533	346	1565	1,018	4,320	3,147	1,565	1,018	746	485	4320	3,147
calves sales	0	0	0	0	0	0	0	0	62	60,191	0	0	0	0	48	46,777
cull cow sales	0	0	0	0	0	0	0	0	9	19,081	0	0	0	0	7	14,828
deer income			50	927	0	0	50	927	50	927	50	927	50	927	0	0
Gross output		**48,066**		**23,577**		**16,314**		**48,886**		**322,771**		**48,886**		**23,782**		**304,178**
less replacement costs																
replacement hogg	279	-5,021	131	-2,366	95	-1,704	278	-5,010	768	-85,403	278	-5,010	133	-2,388	768	-85,403
replacement heifer	0	0	0	0	0	0	0	0	10	-15,385	0	0	0	0	8	-11,956
Net output (a)		**43,044**		**21,210**		**14,610**		**43,876**		**221,984**		**43,876**		**21,394**		**206,819**
Variable costs																
Feeds:																
Forage Cost of inbye use (ha)	174	-1,366	13	-105	13	-105	174	-1,366	174	-1,366	174	-1,366	13	-105	13	-105
Cost of silage produced (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hay bought (t)	0	0	0	0	0	0	0	0	591	-53,206	0	0	0	0	636	-57,246
Concentrates bought (t)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost of ewe	981	-11,120	462	-5,240	333	-3,774	978	-11,095	2,700	-30,279	978	-11,095	466	-5,288	2700	-30,279
Cost of cow	0	0	0	0	0	0	0	0	70	-10,150	0	0	0	0	54	-7,888
total variable costs (b)		**-12,486**		**-5,345**		**-3,880**		**-12,461**		**-95,000**		**-12,461**		**-5,393**		**-95,518**
Gross Margin (c) = (a) + (b)		**30,559**		**15,865**		**10,730**		**31,415**		**126,983**		**31,415**		**16,001**		**111,301**
Fixed costs																
Labour:																
permanent (men)	0	0	0	0	0	0	0	0	1	-25,000	0	0	0	0	1	-25,000
permanent overtime (hours)	0	0	0	0	0	0	0	0	118	-1,652	0	0	0	0	118	-1,652
casual (hours)	938	-13,035	444	-6,163	317	-4,403	935	-12,996	1,763	-24,336	935	-12,996	448	-6,218	1,512	-21,188
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed rent)	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-54,302**		**-47,430**		**-45,670**		**-54,263**		**-92,255**		**-54,263**		**-47,485**		**-89,107**
Farm Net Margin (e) = (c) + (d)		**-23,744**		**-31,565**		**-34,940**		**-22,848**		**34,729**		**-22,848**		**-31,484**		**22,194**
Subsidies																
SFP	1	68,957	1	68,957	1	68,957	0	0	0	0	0	0	0	0	0	0
LFASS	1	7,734	1	3,645	1	2,625	0	0	0	0	1	7,717	0	0	0	0
Farm Net Margin after subsidies (f)		**52,948**		**41,036**		**36,642**		**-22,848**		**34,729**		**-15,131**		**-31,484**		**22,194**
Diversification income (g)																
Forestry (after 16 yrs) (ha)	0	0	214	46,032	214	46,032	0	0	0	0	0	0	214	46,032	214	46,032
Farm Business Income (f) + (g)		**52,948**		**87,068**		**82,674**		**-22,848**		**34,729**		**-15,131**		**14,548**		**68,226**

Outputs:	HMP number of units	£	HF&E number of units	£	HF&E+NSc number of units	£	MCCa_5%_1yr_0x number of units	£	MCCa5%_1yr number of units	£	MCCb number of units	£	MCCb_160% number of units	£
lambs sales	1968	169,086	226	13,854	226	13,854	2,213	117,411	2,213	117,411	295	15,632	165	8,730
draft ewe sales	598	70,339	69	2,907	69	2,907	457	19,199	457	19,199	90	3,761	50	2,100
wool sales (kg)	4320	3,147	500	325	500	325	4,320	2,808	4,320	2,808	647	420	361	235
calves sales	48	46,777	0	0	0	0	17	10,638	17	10,638	0	0	0	0
cull cow sales	7	14,828	0	0	0	0	2	1,500	2	1,500	0	0	0	0
deer income	0	0	50	927	50	927	50	927	50	927	50	927	50	927
Gross output		**304,178**		**18,012**		**18,012**		**152,483**		**152,483**		**20,740**		**11,991**
less replacement costs														
replacement hogg	768	-85,403	89	-2,416	89	-2,416	638	-11,485	638	-11,485	115	-2,070	64	-1,156
replacement heifer	8	-11,956	0	0	0	0	3	-2,620	3	-2,620	0	0	0	0
Net output (a)		**206,819**		**15,596**		**15,596**		**138,377**		**138,377**		**18,670**		**10,835**
Variable costs														
Feeds:														
Forage Cost of inbye use (ha)	13	-105	13	-159	13	-159	13	-105	13	-105	0	0	0	0
Cost of silage produced (ha)	0	0	0	0	0	0	4	-2,473	4	-2,473	0	0	0	0
Hay bought (t)	636	-57,246	0	0	0	0	476	-42,853	476	-42,853	0	0	0	0
Concentrates bought (t)	0	0	0	0	0	0	7	-1,379	7	-1,379	0	0	0	0
Cost of ewe	2700	-30,279	312	-4,878	312	-4,878	2,700	-19,818	2,700	-30,618	404	-4,584	226	-2,560
Cost of cow	54	-7,888	0	0	0	0	18	-2,330	18	-2,660	0	0	0	0
total variable costs (b)		**-95,518**		**-5,037**		**-5,037**		**-68,958**		**-80,089**		**-4,584**		**-2,560**
Gross Margin (c) = (a) + (b)		**111,301**		**10,559**		**10,559**		**69,418**		**58,288**		**14,086**		**8,275**
Fixed costs														
Labour:														
permanent (men)	1	-25,000	0	0	0	0	1	-25,000	1	-25,000	0	0	0	0
permanent overtime (hours)	118	-1,652	0	0	0	0	118	-1,652	118	-1,652	0	0	0	0
casual (hours)	1,512	-21,188	307	-4,251	307	-4,251	1,161	-17,416	1,161	-17,416	389	-5,398	219	-3,037
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed rent)	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-89,107**		**-45,518**		**-45,518**		**-85,335**		**-85,335**		**-46,665**		**-44,304**
Farm Net Margin (e) = (c) + (d)		**22,194**		**-34,959**		**-34,959**		**-15,917**		**-27,047**		**-32,578**		**-36,029**
Subsidies														
SFP	1	68,957	1	68,957	1	0	1	68,957	1	68,957	1	68,957	1	68,957
LFASS	1	16,920	1	2,464	1	0	1	12,531	1	12,531	1	3,188	1	1,780
Farm Net Margin after subsidies (f)		**108,070**		**36,462**		**-34,959**		**65,571**		**54,441**		**39,567**		**34,708**
Diversification income (g)														
Forestry (after 16 yrs) (ha)	214	46,032	214	40,682	214	40,682	214	46,032	214	46,032	257	52,921	560	89,837
Farm Business Income (f) + (g)		**154,102**		**77,143**		**5,722**		**111,603**		**100,473**		**92,487**		**124,545**

IX.2.2. Adaptive farmers scenarios

Outputs:	W/D+AF number of units	£	AoH+AF number of units	£	NSa+AF number of units	£	NSb+AF umber of unit	£	NSc+AF number of units	£	NSd+AF number of units	£
lambs sales	337	17,870	240	12,756	720	38,181	720	38,181	340	18,032	1968	169,086
draft ewe sales	102	4,299	73	3,069	219	9,186	219	9,186	103	4,338	598	70,339
wool sales (kg)	739	481	528	343	1580	1,027	1,580	1,027	746	485	4320	3,147
calves sales	0	0	0	0	0	0	0	0	0	0	48	46,777
cull cow sales	0	0	0	0	0	0	0	0	0	0	7	14,828
deer income	50	927	0	0	50	927	50	927	50	927	0	0
Gross output		**23,577**		**16,168**		**49,320**		**49,320**		**23,782**		**304,178**
less replacement costs												
replacement hogg	131	-2,366	94	-1,689	281	-5,056	281	-5,056	133	-2,388	768	-85,403
replacement heifer	0	0	0	0	0	0	0	0	0	0	8	-11,956
Net output (a)		**21,210**		**14,479**		**44,264**		**44,264**		**21,394**		**206,819**
Variable costs												
Feeds:												
Forage Cost of inbye use (ha)	13	-105	13	-105	174	-1,366	174	-1,366	13	-105	13	-105
Cost of silage produced (ha)	0	0	0	0	0	0	0	0	0	0	0	0
Hay bought (t)	0	0	0	0	0	0	0	0	0	0	636	-57,246
Concentrates bought (t)	0	0	0	0	0	0	0	0	0	0	0	0
Cost of ewe	462	-5,240	330	-3,740	987	-11,196	987	-11,196	466	-5,288	2700	-30,279
Cost of cow	0	0	0	0	0	0	0	0	0	0	54	-7,888
total variable costs (b)		**-5,345**		**-3,846**		**-12,561**		**-12,561**		**-5,393**		**-95,518**
Gross Margin (c) = (a) + (b)		**15,865**		**10,633**		**31,703**		**31,703**		**16,001**		**111,301**
Fixed costs												
Labour:												
permanent (men)	0	0	0	0	0	0	0	0	0	0	1	-25,000
permanent overtime (hours)	0	0	0	0	0	0	0	0	0	0	118	-1,652
casual (hours)	488	-6,780	345	-4,800	1,038	-14,424	1,038	-14,424	492	-6,840	1,906	-26,452
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed re	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-48,047**		**-46,067**		**-55,691**		**-55,691**		**-48,107**		**-94,371**
Farm Net Margin (e) = (c) + (d)		**-32,182**		**-35,434**		**-23,988**		**-23,988**		**-32,106**		**16,930**
Subsidies												
SFP	1	68,957	1	68,957	0	0	0	0	0	0	0	0
LFASS	1	3,645	1	2,602	0	0	1	7,787	0	0	0	0
Farm Net Margin after subsidies (f)		**40,420**		**36,124**		**-23,988**		**-16,201**		**-32,106**		**16,930**
Diversification income (g)												
Forestry (after 16 yrs) (ha)	214	46,032	214	46,032	0	0	0	0	214	46,032	214	46,032
Farm Business Income (f) + (g)		**86,452**		**82,156**		**-23,988**		**-16,201**		**13,926**		**62,962**

	HMP+AF		HF&E+AF		MCCa_5%_1yr_0x +AF		MCCa_5%_1yr +AF		MCCb +AF	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	1968	169,086	224	13,770	2213	117,411	2213	117,411	287	15,249
draft ewe sales	598	70,339	69	2,889	457	19,199	457	19,199	87	3,669
wool sales (kg)	4320	3,147	497	323	4320	2,808	4320	2,808	631	410
calves sales	48	46,777	0	0	11	6,985	11	6,985	0	0
cull cow sales	7	14,828	0	0	1	985	1	985	0	0
deer income	0	0	50	927	50	927	50	927	50	927
Gross output		**304,178**		**17,909**		**148,315**		**148,315**		**20,254**
less replacement costs										
replacement hogg	768	-85,403	88	-2,401	638	-11,485	638	-11,485	112	-2,019
replacement heifer	8	-11,956	0	0	2	-1,721	2	-1,721	0	0
Net output (a)		**206,819**		**15,508**		**135,109**		**135,109**		**18,235**
Variable costs										
Feeds:										
Forage Cost of inbye use (ha)	13	-105	13	-159	13	-105	13	-105	0	0
Cost of silage produced (ha)	0	0	0	0	3	-1,472	3	-1,472	0	0
Hay bought (t)	636	-57,246	0	0	471	-42,360	471	-42,360	0	0
Concentrates bought (t)	0	0	0	0	4	-821	4	-821	0	0
Cost of ewe	2700	-30,279	311	-4,849	2700	-19,818	2700	-30,618	394	-4,471
Cost of cow	54	-7,888	0	0	12	-1,530	12	-1,746	0	0
total variable costs (b)		**-95,518**		**-5,008**		**-66,105**		**-77,122**		**-4,471**
Gross Margin (c) = (a) + (b)		**111,301**		**10,500**		**69,004**		**57,987**		**13,764**
Fixed costs										
Labour:										
permanent (men)	1	-25,000	0	0	1	-25,000	1	-25,000	0	0
permanent overtime (hours)	118	-1,652	0	0	118	-1,652	118	-1,652	0	0
casual (hours)	1,906	-26,452	336	-4,649	1,334	-20,016	1,334	-20,016	417	-5,794
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed re	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-94,371**		**-45,916**		**-87,935**		**-87,935**		**-47,061**
Farm Net Margin (e) = (c) + (d)		**16,930**		**-35,416**		**-18,931**		**-29,948**		**-33,297**
Subsidies										
SFP	1	68,957	1	68,957	1	68,957	1	68,957	1	68,957
LFASS	1	16,920	1	2,449	1	12,531	1	12,531	1	3,110
Farm Net Margin after subsidies (f)		**102,807**		**35,991**		**62,557**		**51,540**		**38,770**
Diversification income (g)										
Forestry (after 16 yrs) (ha)	214	46,032	214	40,682	214	46,032	214	46,032	257	52,921
Farm Business Income (f) + (g)		**148,839**		**76,672**		**108,589**		**97,572**		**91,690**

IX.2.3. Focused farmers scenarios

	W/D +FF		AoH+FF		NSa+FF		NSb+FF		NSd+FF		HMP+FF		HF&E+FF		MCCa_5%_1y_0x +FF		MCCa_5%_1y +FF	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	715	37,922	622	33,020	715	37,922	739	39,228	1968	169,086	1968	169,086	491	30,139	2213	117,411	2,213	117,411
draft ewe sales	217	9,124	189	7,944	217	9,124	225	9,438	598	70,339	598	70,339	151	6,324	457	19,199	457	19,199
wool sales (kg)	1569	1,020	1366	888	1569	1,020	1,623	1,055	4320	3,147	4320	3,147	1088	707	4320	2,808	4,320	2,808
calves sales	0	0	0	0	0	0	0	0	62	60,191	62	60,191	0	0	0	0	0	0
cull cow sales	0	0	0	0	0	0	0	0	9	19,081	9	19,081	0	0	0	0	0	0
deer income	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gross output		**48,066**		**41,852**		**48,066**		**49,721**		**321,845**		**321,845**		**37,169**		**139,418**		**139,418**
less replacement costs																		
replacement hogg	279	-5,021	243	-4,372	279	-5,021	289	-5,194	768	-85,403	768	-85,403	193	-5,256	638	-11,485	638	-11,485
replacement heifer	0	0	0	0	0	0	0	0	10	-15,385	10	-15,385	0	0	0	0	0	0
Net output (a)		**43,044**		**37,480**		**43,044**		**44,526**		**221,057**		**221,057**		**31,914**		**127,933**		**127,933**
Variable costs																		
Feeds:																		
Forage Cost of inbye use (ha)	174	-1,366	174	-1,366	174	-1,366	174	-1,366	174	-1,366	174	-1,366	174	-2,062	174	-1,366	174	-1,366
Cost of silage produced (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hay bought (t)	0	0	0	0	0	0	0	0	581	-52,250	581	-52,250	0	0	348	-31,282	348	-31,282
Concentrates bought (t)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost of ewe	981	-11,120	854	-9,683	981	-11,120	1,014	-11,503	2700	-30,279	2700	-30,279	680	-10,613	2700	-19,818	2,700	-30,618
Cost of cow	0	0	0	0	0	0	0	0	70	-10,150	70	-10,150	0	0	0	0	0	0
total variable costs (b)		**-12,486**		**-11,048**		**-12,486**		**-12,868**		**-94,045**		**-94,045**		**-12,675**		**-52,466**		**-63,266**
Gross Margin (c) = (a) + (b)		**30,559**		**26,432**		**30,559**		**31,658**		**127,013**		**127,013**		**19,239**		**75,467**		**64,667**
Fixed costs																		
Labour:																		
permanent (men)	0	0	0	0	0	0	0	0	1	-25,000	1	-25,000	0	0	1	-16,548	1	-16,548
permanent overtime (hours)	0	0	0	0	0	0	0	0	118	-1,652	118	-1,652	0	0	78	-1,093	78	-1,093
casual (hours)	938	-13,035	812	-11,301	938	-13,035	970	-13,481	1,757	-24,267	1,757	-24,267	664	-9,201	1,445	-21,446	1,445	-21,446
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed re	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-54,302**		**-52,568**		**-54,302**		**-54,748**		**-92,186**		**-92,186**		**-50,468**		**-80,354**		**-80,354**
Farm Net Margin (e) = (c) + (d)		**-23,744**		**-26,136**		**-23,744**		**-23,090**		**34,827**		**34,827**		**-31,229**		**-4,888**		**-15,688**
Subsidies																		
SFP	1	68,957	1	68,957	0	0	0	0	0	0	1	68,957	1	68,957	1	68,957	1	68,957
LFASS	1	7,734	1	4,531	0	0	1	8,001	0	0	1	18,744	1	5,361	1	13,882	1	13,882
Farm Net Margin after subsidies (f)		**52,948**		**47,352**		**-23,744**		**-15,089**		**34,827**		**122,528**		**43,089**		**77,951**		**67,151**
Diversification income (g)																		
Forestry (after 16 yrs) (ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm Business Income (f) + (g)		**52,948**		**47,352**		**-23,744**		**-15,089**		**34,827**		**122,528**		**43,089**		**77,951**		**67,151**

IX.2.4. Constrained farmers scenarios

IX.2.4.1.Constrained farmers – both deer shooting and woodland diversification

	W/D +CF		AoH+CF		NSa+CF		NSb+CF		NSc+CF		NSd+CF	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	234	12,422	156	8,294	576	30,545	576	30,545	234	12,422	1575	135,269
draft ewe sales	71	2,989	48	1,995	175	7,349	175	7,349	71	2,989	478	56,271
wool sales (kg)	514	334	343	223	1264	821	1,264	821	514	334	3456	2,518
calves sales	0	0	0	0	0	0	0	0	0	0	38	37,186
cull cow sales	0	0	0	0	0	0	0	0	0	0	6	11,788
deer income	40	741	0	0	40	741	40	741	40	741	0	0
Gross output		**16,486**		**10,512**		**39,456**		**39,456**		**16,486**		**243,032**
less replacement costs												
replacement hogg	91	-1,645	61	-1,098	225	-4,045	225	-4,045	91	-1,645	614	-68,322
replacement heifer	0	0	0	0	0	0	0	0	0	0	6	-9,505
Net output (a)		**14,841**		**9,414**		**35,411**		**35,411**		**14,841**		**165,206**
Variable costs												
Feeds:												
Forage Cost of inbye use (ha)	0	0	0	0	139	-1,092	139	-1,092	0	0	4	-33
Cost of silage produced (ha)	0	0	0	0	0	0	0	0	0	0	6	-3,176
Hay bought (t)	0	0	0	0	0	0	0	0	0	0	451	-40,600
Concentrates bought (t)	0	0	0	0	0	0	0	0	0	0	9	-1,772
Cost of ewe	321	-3,643	214	-2,432	790	-8,957	790	-8,957	321	-3,643	2160	-24,223
Cost of cow	0	0	0	0	0	0	0	0	0	0	43	-6,271
total variable costs (b)		**-3,643**		**-2,432**		**-10,049**		**-10,049**		**-3,643**		**-76,075**
Gross Margin (c) = (a) + (b)		**11,198**		**6,982**		**25,362**		**25,362**		**11,198**		**89,131**
Fixed costs												
Labour:												
permanent (men)	0	0	0	0	0	0	0	0	0	0	1	-25,000
permanent overtime (hours)	0	0	0	0	0	0	0	0	0	0	118	-1,652
casual (hours)	309	-4,289	204	-2,837	755	-10,490	755	-10,490	309	-4,289	847	-12,115
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed re	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-45,556**		**-44,104**		**-51,757**		**-51,757**		**-45,556**		**-80,034**
Farm Net Margin (e) = (c) + (d)		**-34,358**		**-37,122**		**-26,395**		**-26,395**		**-34,358**		**9,097**
Subsidies												
SFP	1	55,165	1	55,165	0	0	0	0	0	0	0	0
LFASS	1	2,534	1	1,692	0	0	1	6,230	0	0	0	0
Farm Net Margin after subsidies (f)		**23,341**		**19,735**		**-26,395**		**-20,165**		**-34,358**		**9,097**
Diversification income (g)												
Forestry (after 16 yrs) (ha)	214	43,381	214	43,381	0	0	0	0	214	43,381	214	42,440
Farm Business Income (f) + (g)		**66,722**		**63,116**		**-26,395**		**-20,165**		**9,023**		**51,537**

	HMP+CF		HF&E+CF		MCCa_5%_1yr_0x +CF		MCCa_5%_1yr+CF		MCCb+CF	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	1575	135,269	162	9,911	1771	93,929	1771	93,929	214	11,334
draft ewe sales	478	56,271	50	2,080	366	15,359	366	15,359	65	2,727
wool sales (kg)	3456	2,518	358	232	3456	2,246	3456	2,246	469	305
calves sales	38	37,186	0	0	0	0	0	0	0	0
cull cow sales	6	11,788	0	0	0	0	0	0	0	0
deer income	0	0	40	741	40	741	40	741	40	741
Gross output		**243,032**		**12,965**		**112,276**		**112,276**		**15,107**
less replacement costs										
replacement hogg	614	-68,322	64	-1,728	510	-9,188	510	-9,188	83	-1,501
replacement heifer	6	-9,505	0	0	0	0	0	0	0	0
Net output (a)		**165,206**		**11,236**		**103,087**		**103,087**		**13,606**
Variable costs										
Feeds:										
Forage Cost of inbye use (ha)	4	-33	0	0	0	0	0	0	0	0
Cost of silage produced (ha)	6	-3,176	0	0	0	0	0	0	0	0
Hay bought (t)	451	-40,600	0	0	383	-34,487	383	-34,487	0	0
Concentrates bought (t)	9	-1,772	0	0	0	0	0	0	0	0
Cost of ewe	2160	-24,223	224	-3,490	2160	-15,854	2160	-24,494	293	-3,323
Cost of cow	43	-6,271	0	0	0	0	0	0	0	0
total variable costs (b)		**-76,075**		**-3,490**		**-50,342**		**-58,982**		**-3,323**
Gross Margin (c) = (a) + (b)		**89,131**		**7,746**		**52,745**		**44,105**		**10,282**
Fixed costs										
Labour:										
permanent (men)	1	-25,000	0	0	0	0	0	0	0	0
permanent overtime (hours)	118	-1,652	0	0	0	0	0	0	0	0
casual (hours)	847	-12,115	220	-3,044	2,503	-34,579	2,503	-34,579	282	-3,917
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed rent)	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-80,034**		**-44,311**		**-75,846**		**-75,846**		**-45,184**
Farm Net Margin (e) = (c) + (d)		**9,097**		**-36,564**		**-23,100**		**-31,740**		**-34,902**
Subsidies										
SFP	1	55,165	1	55,165	1	55,165	1	55,165	1	55,165
LFASS	1	13,171	1	1,763	1	9,755	1	9,755	1	2,312
Farm Net Margin after subsidies (f)		**77,434**		**20,364**		**41,820**		**33,180**		**22,575**
Diversification income (g)										
Forestry (after 16 yrs) (ha)	214	42,440	228	38,149	214	43,381	214	43,381	257	48,605
Farm Business Income (f) + (g)		**119,874**		**58,513**		**85,201**		**76,561**		**71,180**

IX.2.4.2. Constrained farmers-without deer shooting diversification

	W/D + CFnd		AoH+CFnd		Nsa_CFnd		Nsb_CFnd		NSc_CFnd		NSc_CFnd	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	250	13,260	156	8,294	592	31,382	592	31,382	250	13,260	1575	135,269
draft ewe sales	76	3,190	48	1,995	180	7,550	180	7,550	76	3,190	478	56,271
wool sales (kg)	549	357	343	223	1298	844	1,298	844	549	357	3456	2,518
calves sales	0	0	0	0	0	0	0	0	0	0	38	37,186
cull cow sales	0	0	0	0	0	0	0	0	0	0	6	11,788
deer income	0	0	0	0	0	0	0	0	0	0	0	0
Gross output		**16,806**		**10,512**		**39,776**		**39,776**		**16,806**		**243,032**
less replacement costs												
replacement hogg	98	-1,756	61	-1,098	231	-4,155	231	-4,155	98	-1,756	614	-68,322
replacement heifer	0	0	0	0	0	0	0	0	0	0	6	-9,505
Net output (a)		**15,051**		**9,414**		**35,621**		**35,621**		**15,051**		**165,206**
Variable costs												
Feeds:												
Forage Cost of inbye use (ha)	0	0	0	0	139	-1,092	139	-1,092	0	0	4	-33
Cost of silage produced (ha)	0	0	0	0	0	0	0	0	0	0	6	-3,176
Hay bought (t)	0	0	0	0	0	0	0	0	0	0	451	-40,600
Concentrates bought (t)	0	0	0	0	0	0	0	0	0	0	9	-1,772
Cost of ewe	343	-3,888	214	-2,432	811	-9,202	811	-9,202	343	-3,888	2160	-24,223
Cost of cow	0	0	0	0	0	0	0	0	0	0	43	-6,271
total variable costs (b)		**-3,888**		**-2,432**		**-10,295**		**-10,295**		**-3,888**		**-76,075**
Gross Margin (c) = (a) + (b)		**11,163**		**6,982**		**25,326**		**25,326**		**11,163**		**89,131**
Fixed costs												
Labour:												
permanent (men)	0	0	0	0	0	0	0	0	0	0	1	-25,000
permanent overtime (hours)	0	0	0	0	0	0	0	0	0	0	118	-1,652
casual (hours)	330	-4,584	204	-2,837	776	-10,785	776	-10,785	330	-4,584	847	-12,115
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed re	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-45,851**		**-44,104**		**-52,052**		**-52,052**		**-45,851**		**-80,034**
Farm Net Margin (e) = (c) + (d)		**-34,688**		**-37,122**		**-26,726**		**-26,726**		**-34,688**		**9,097**
Subsidies												
SFP	1	55,165	1	55,165	0	0	0	0	0	0	0	0
LFASS	1	2,704	1	1,692	0	0	1	6,401	0	0	0	0
Farm Net Margin after subsidies (f)		**23,181**		**19,735**		**-26,726**		**-20,325**		**-34,688**		**9,097**
Diversification income (g)												
Forestry (after 16 yrs) (ha)	214	43,381	214	43,381	0	0	0	0	214	43,381	214	42,440
Farm Business Income (f) + (g)		**66,563**		**63,116**		**-26,726**		**-20,325**		**8,693**		**51,537**

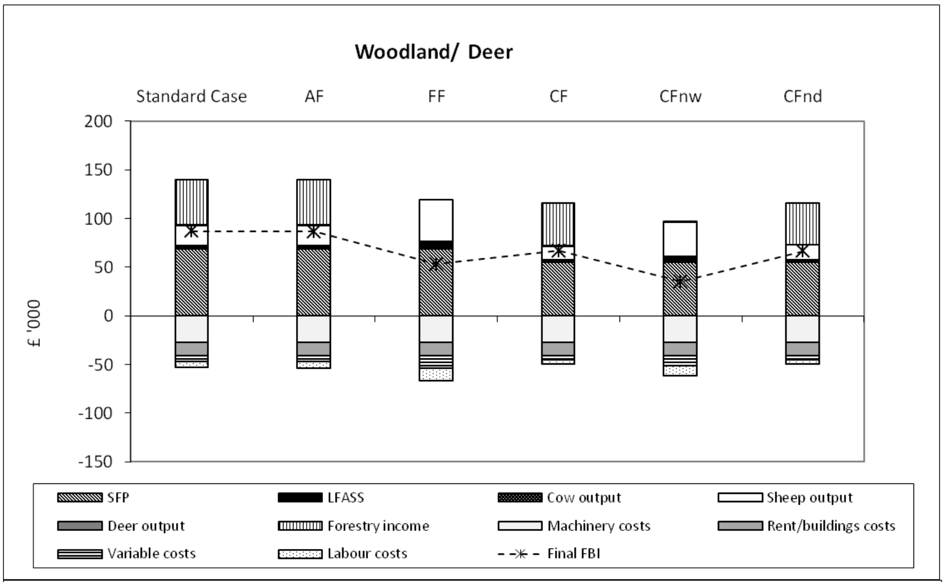
	HMP+CFnd		HF&E+CFnd		MCCa_5%_1yr_0x+ CFnd		MCCa_5%_1yr+CFnd		MCCb+CFnd	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	1575	135,269	172	10,555	1771	93,929	1771	93,929	229	12,164
draft ewe sales	478	56,271	53	2,215	366	15,359	366	15,359	70	2,927
wool sales (kg)	3456	2,518	381	248	3456	2,246	3456	2,246	503	327
calves sales	38	37,186	0	0	0	0	0	0	0	0
cull cow sales	6	11,788	0	0	0	0	0	0	0	0
deer income	0	0	0	0	0	0	0	0	0	0
Gross output		**243,032**		**13,017**		**111,534**		**111,534**		**15,418**
less replacement costs										
replacement hogg	614	-68,322	68	-1,841	510	-9,188	510	-9,188	89	-1,611
replacement heifer	6	-9,505	0	0	0	0	0	0	0	0
Net output (a)		**165,206**		**11,177**		**102,346**		**102,346**		**13,807**
Variable costs										
Feeds:										
Forage Cost of inbye use (ha)	4	-33	0	0	0	0	0	0	0	0
Cost of silage produced (ha)	6	-3,176	0	0	0	0	0	0	0	0
Hay bought (t)	451	-40,600	0	0	379	-34,085	379	-34,085	0	0
Concentrates bought (t)	9	-1,772	0	0	0	0	0	0	0	0
Cost of ewe	2160	-24,223	238	-3,717	2160	-15,854	2160	-24,494	315	-3,567
Cost of cow	43	-6,271	0	0	0	0	0	0	0	0
total variable costs (b)		**-76,075**		**-3,717**		**-49,940**		**-58,580**		**-3,567**
Gross Margin (c) = (a) + (b)		**89,131**		**7,460**		**52,406**		**43,766**		**10,240**
Fixed costs										
Labour:										
permanent (men)	1	-25,000	0	0	0	0	0	0	0	0
permanent overtime (hours)	118	-1,652	0	0	0	0	0	0	0	0
casual (hours)	847	-12,115	235	-3,247	2,501	-34,554	2,501	-34,554	303	-4,209
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed rent)	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-80,034**		**-44,514**		**-75,821**		**-75,821**		**-45,476**
Farm Net Margin (e) = (c) + (d)		**9,097**		**-37,054**		**-23,414**		**-32,054**		**-35,236**
Subsidies										
SFP	1	55,165	1	55,165	1	55,165	1	55,165	1	55,165
LFASS	1	13,171	1	1,878	1	9,755	1	9,755	1	2,481
Farm Net Margin after subsidies (f)		**77,434**		**19,989**		**41,506**		**32,866**		**22,410**
Diversification income (g)										
Forestry (after 16 yrs) (ha)	214	42,440	228	38,149	214	43,381	214	43,381	257	48,605
Farm Business Income (f) + (g)		**119,874**		**58,138**		**84,887**		**76,247**		**71,015**

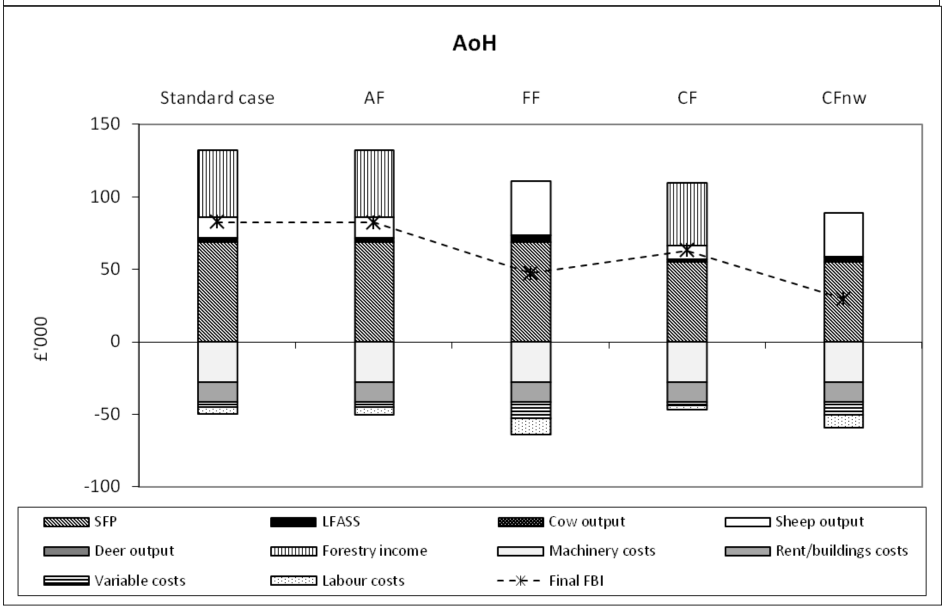
IX.2.4.3. Constrained farmers – no woodland diversification

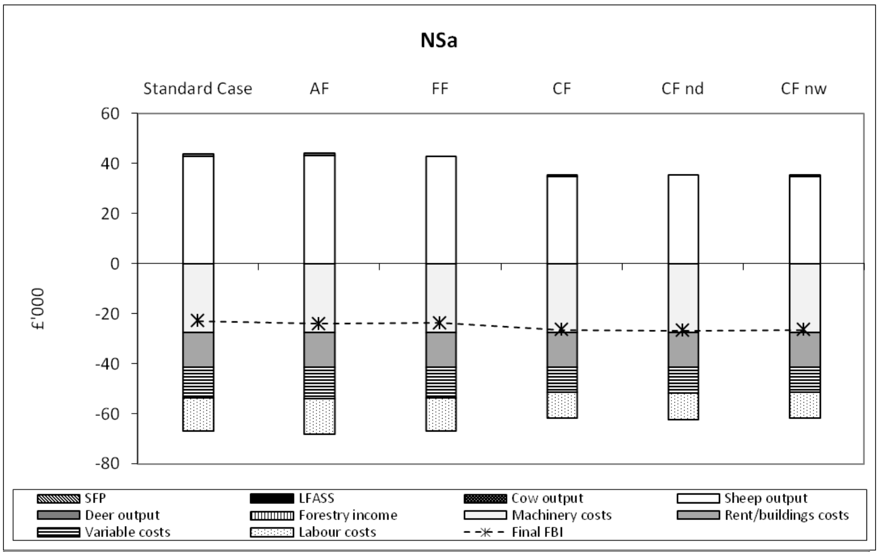
	W/D +CFnw		AoH+CFnw		NSa+CFnw		NSb+CFnw		NSc+CFnw		NSd+CFnw	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	576	30,545	498	26,416	576	30,545	576	30,545	576	30,545	1,575	135,269
draft ewe sales	175	7,349	151	6,355	175	7,349	175	7,349	175	7,349	478	56,271
wool sales (kg)	1264	821	1093	710	1264	821	1264	821	1264	821	3,456	2,518
calves sales	0	0	0	0	0	0	0	0	0	0	49	48,153
cull cow sales	0	0	0	0	0	0	0	0	0	0	7	15,265
deer income	40	741	0	0	40	741	40	741	40	741	40	741
Gross output		**39,456**		**33,482**		**39,456**		**39,456**		**39,456**		**258,217**
less replacement costs												
replacement hogg	225	-4,045	194	-3,498	225	-4,045	225	-4,045	225	-4,045	614	-68,322
replacement heifer	0	0	0	0	0	0	0	0	0	0	8	-12,308
Net output (a)		**35,411**		**29,984**		**35,411**		**35,411**		**35,411**		**177,587**
Variable costs												
Feeds:												
Forage Cost of inbye use (ha)	139	-1,092	139	-1,092	139	-1,092	139	-1,092	139	-1,092	139	-1,092
Cost of silage produced (ha)	0	0	0	0	0	0	0	0	0	0	4	-2,218
Hay bought (t)	0	0	0	0	0	0	0	0	0	0	427	-38,418
Concentrates bought (t)	0	0	0	0	0	0	0	0	0	0	6	-1,237
Cost of ewe	790	-8,957	683	-7,746	790	-8,957	790	-8,957	790	-8,957	2,160	-24,223
Cost of cow	0	0	0	0	0	0	0	0	0	0	56	-8,120
total variable costs (b)		**-10,049**		**-8,838**		**-10,049**		**-10,049**		**-10,049**		**-75,309**
Gross Margin (c) = (a) + (b)		**25,362**		**21,146**		**25,362**		**25,362**		**25,362**		**102,279**
Fixed costs												
Labour:												
permanent (men)	0	0	0	0	0	0	0	0	0	0	1	-25,000
permanent overtime (hours)	0	0	0	0	0	0	0	0	0	0	118	-1,652
casual (hours)	755	-10,490	650	-9,041	755	-10,490	755	-10,490	755	-10,490	1,010	-14,195
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed rent)	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-51,757**		**-50,308**		**-51,757**		**-51,757**		**-51,757**		**-82,114**
Farm Net Margin (e) = (c) + (d)		**-26,395**		**-29,162**		**-26,395**		**-26,395**		**-26,395**		**20,164**
Subsidies												
SFP	1	55,165	1	55,165	0	0	0	0	0	0	1	0
LFASS	1	6,230	1	3,624	0	0	1	6,230	0	0	1	0
Farm Net Margin after subsidies (f)		**35,000**		**29,628**		**-26,395**		**-20,165**		**-26,395**		**20,164**
Diversification income (g)												
Forestry (after 16 yrs) (ha)	0	0	0	0	0	0	0	0	0	0	0	0
Farm Business Income (f) + (g)		**35,000**		**29,628**		**-26,395**		**-20,165**		**-26,395**		**20,164**

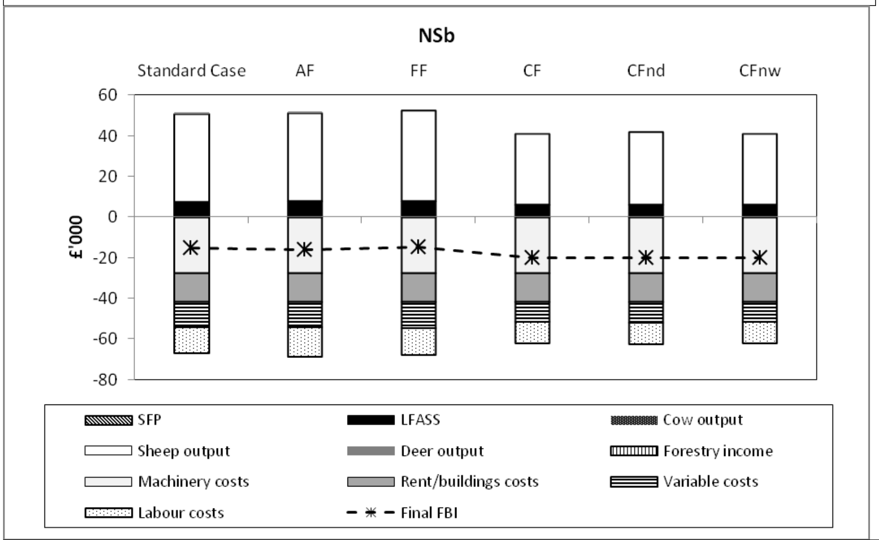
	HMP+CFnw		HF&E+CFnw		MCCa_5%_1yr_0x+CFnw		MCCa_5%_1yr+CFnw	
Outputs:	number of units	£	number of units	£	number of units	£	number of units	£
lambs sales	1575	135,269	382	23,467	1771	93,929	1771	93,929
draft ewe sales	478	56,271	117	4,924	366	15,359	366	15,359
wool sales (kg)	3456	2,518	847	550	3456	2,246	3456	2,246
calves sales	49	48,153	0	0	0	0	0	0
cull cow sales	7	15,265	0	0	0	0	0	0
deer income	40	741	40	741	40	741	40	741
Gross output		**258,217**		**29,683**		**112,276**		**112,276**
less replacement costs								
replacement hogg	614	-68,322	151	-4,092	510	-9,188	510	-9,188
replacement heifer	8	-12,308	0	0	0	0	0	0
Net output (a)		**177,587**		**25,591**		**103,087**		**103,087**
Variable costs								
Feeds:								
Forage Cost of inbye use (ha)	139	-1,092	139	-1,650	139	-1,092	139	-1,092
Cost of silage produced (ha)	4	-2,218	0	0	0	0	0	0
Hay bought (t)	427	-38,418	0	0	287	-25,791	287	-25,791
Concentrates bought (t)	6	-1,237	0	0	0	0	0	0
Cost of ewe	2160	-24,223	529	-8,263	2160	-15,854	2160	-24,494
Cost of cow	56	-8,120	0	0	0	0	0	0
total variable costs (b)		**-75,309**		**-9,913**		**-42,738**		**-51,378**
Gross Margin (c) = (a) + (b)		**102,279**		**15,678**		**60,350**		**51,710**
Fixed costs								
Labour:								
permanent (men)	1	-25,000	0	0	0	0	0	0
permanent overtime (hours)	118	-1,652	0	0	0	0	0	0
casual (hours)	1,010	-14,195	516	-7,158	2,444	-33,866	2,444	-33,866
Machinery: (fuel +maintenance)	1	-14,618	1	-14,618	1	-14,618	1	-14,618
Machinery depreciation	1	-12,774	1	-12,774	1	-12,774	1	-12,774
Land & buildings costs (incl rent & imputed rent)	1	-13,875	1	-13,875	1	-13,875	1	-13,875
total fixed costs (d)		**-82,114**		**-48,425**		**-75,133**		**-75,133**
Farm Net Margin (e) = (c) + (d)		**20,164**		**-32,747**		**-14,783**		**-23,423**
Subsidies								
SFP	1	55,165	1	55,165	1	55,165	1	55,165
LFASS	1	14,995	1	4,174	1	11,106	1	11,106
Farm Net Margin after subsidies (f)		**90,325**		**26,593**		**51,488**		**42,848**
Diversification income (g)								
Forestry (after 16 yrs) (ha)	0	0	0	0	0	0	0	0
Farm Business Income (f) + (g)		**90,325**		**26,593**		**51,488**		**42,848**

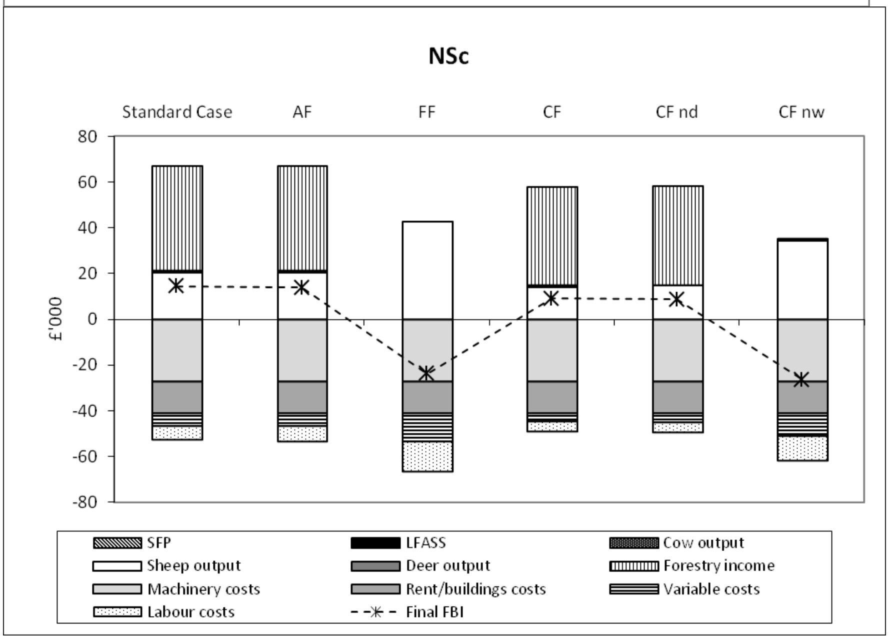
IX.3.Financial throughputs for all profiles and all futures

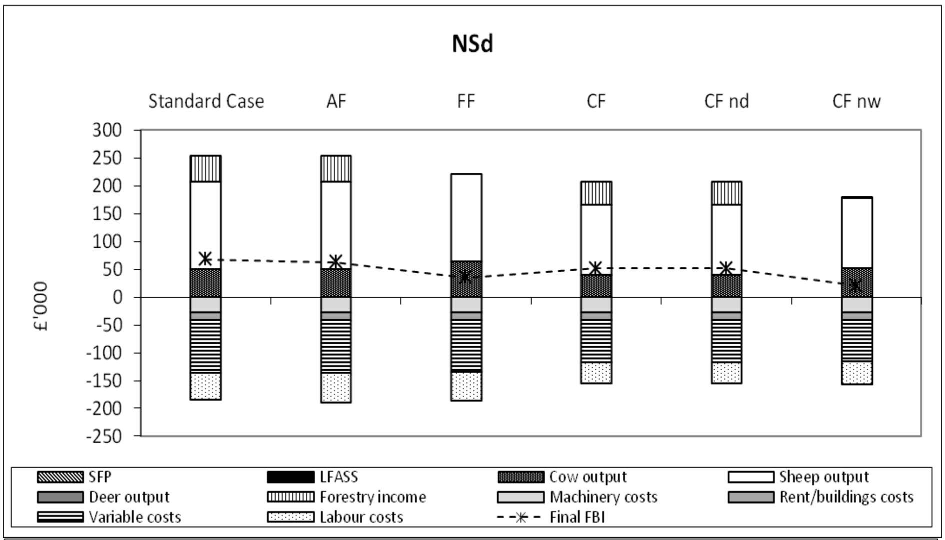


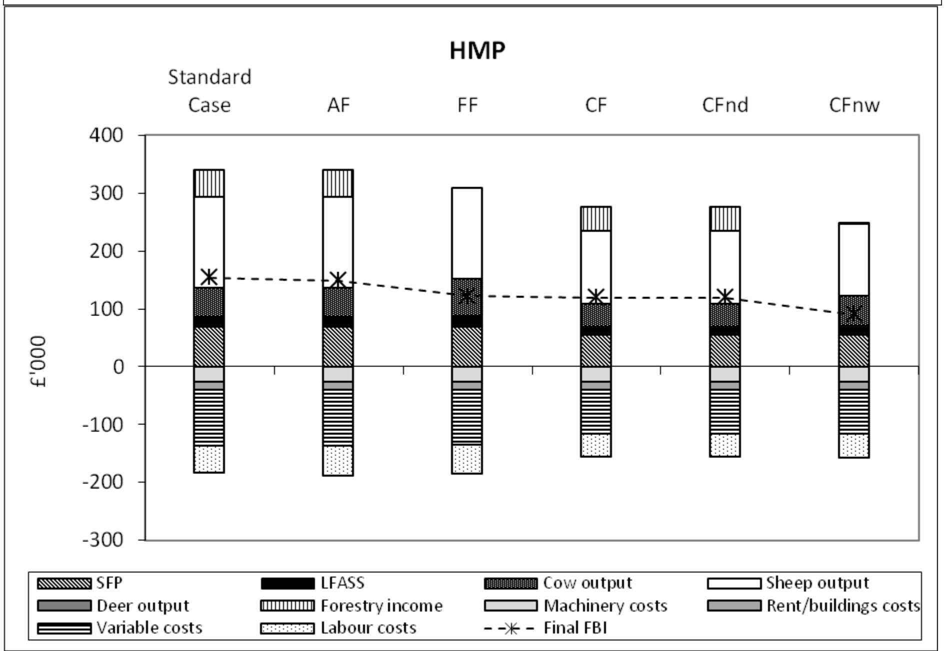


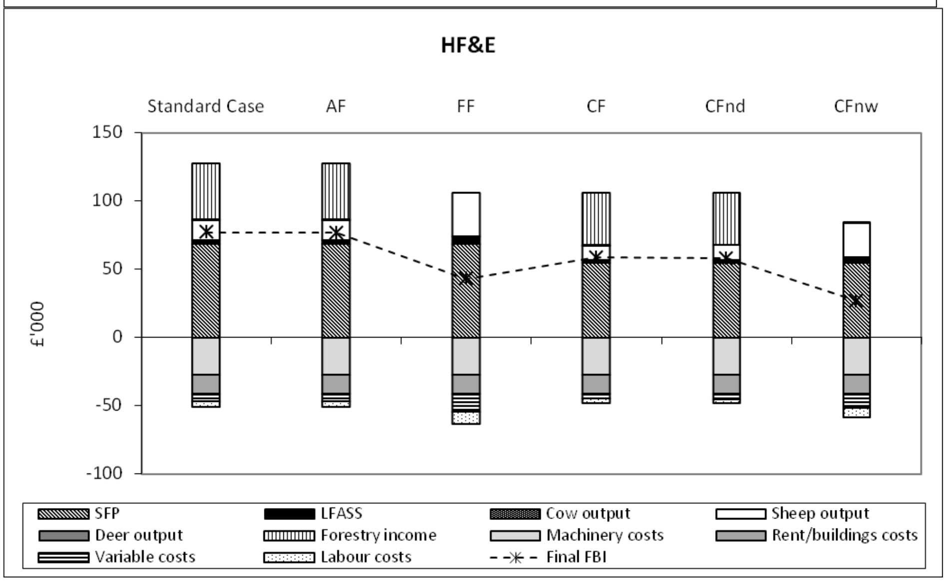

NSa
Standard Case
AF
FF
CF
CF nd
CF nw
£'000
60
40
20
0
-20
-40
-60
-80
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

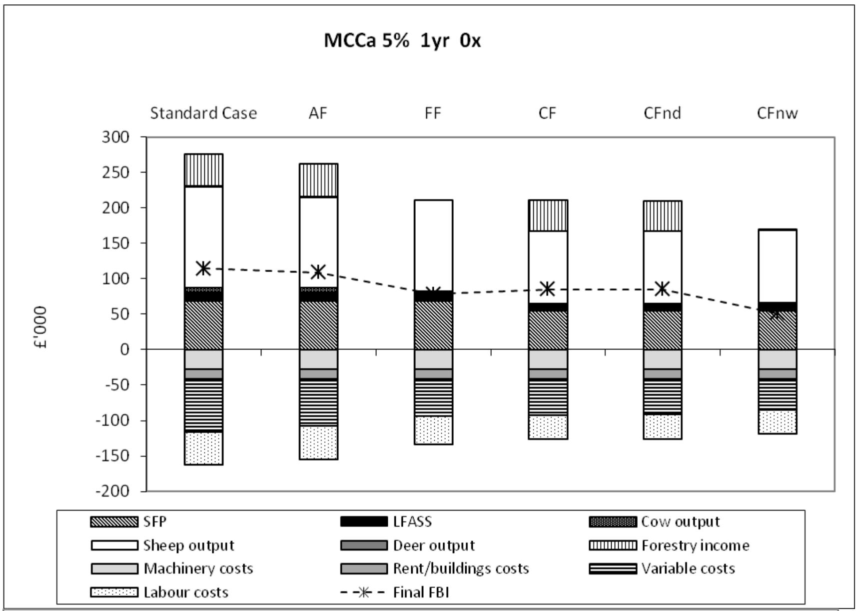

NSb
Standard Case
AF
FF
CF
CFnd
CFnw
£'000
60
40
20
0
-20
-40
-60
-80
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

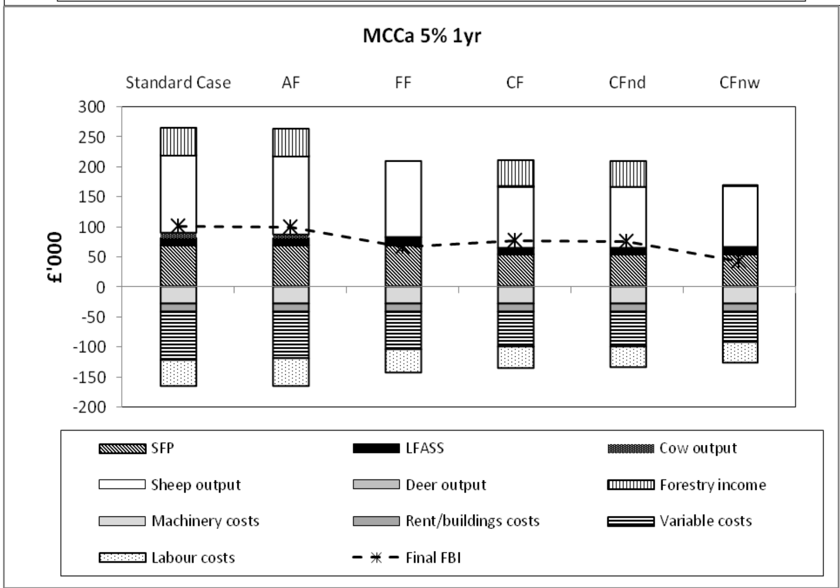

NSc
Standard Case
AF
FF
CF
CF nd
CF nw
£'000
80
60
40
20
0
-20
-40
-60
-80
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

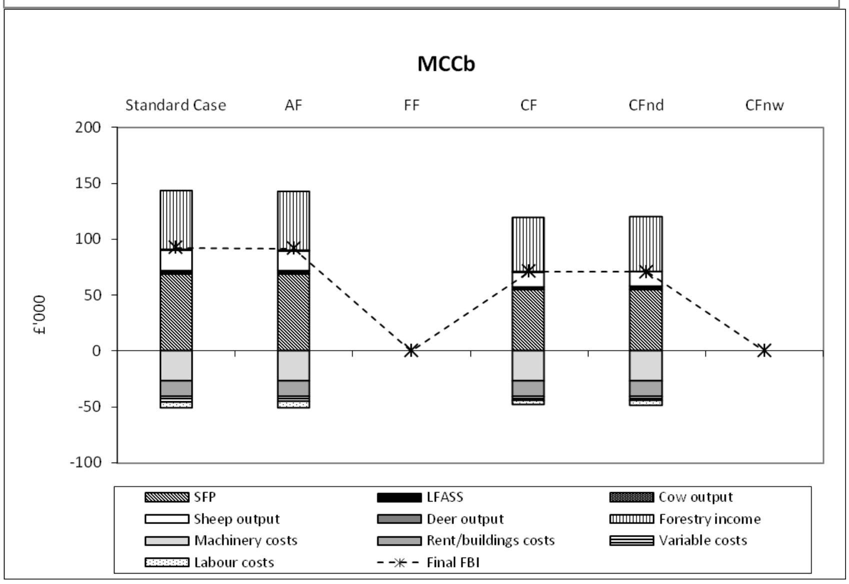

NSd
Standard Case
AF
FF
CF
CF nd
CF nw
£'000
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI


HMP
Standard Case
AF
FF
CF
CFnd
CFnw
£'000
400
300
200
100
0
-100
-200
-300
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

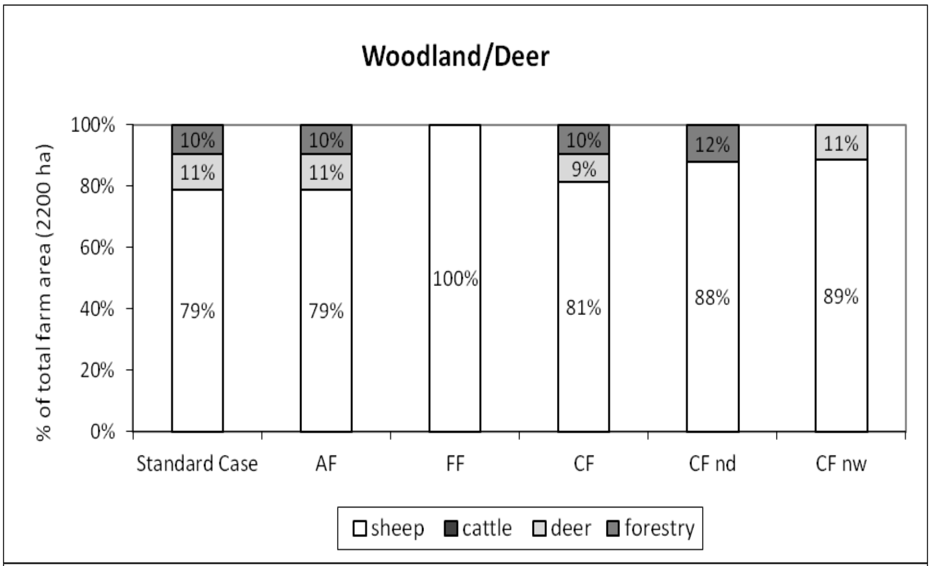

HF&E
Standard Case
AF
FF
CF
CFnd
CFnw
£'000
150
100
50
0
-50
-100
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

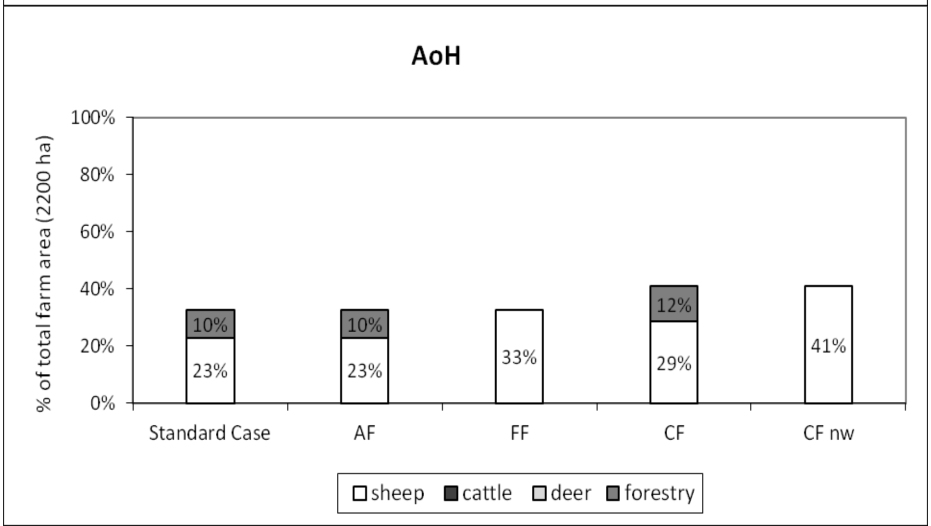

MCCa 5% 1yr 0x
Standard Case
AF
FF
CF
CFnd
CFnw
£'000
300
250
200
150
100
50
0
-50
-100
-150
-200
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

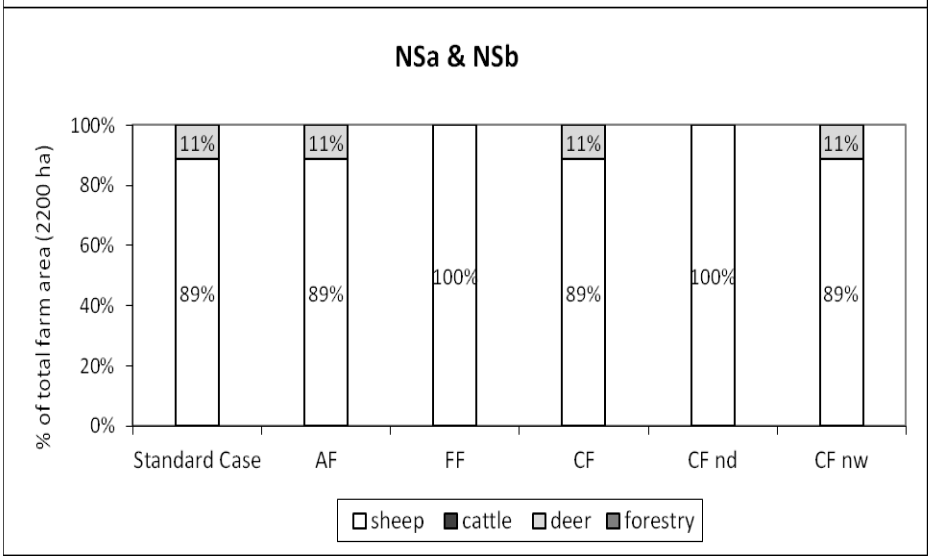

MCCa 5% 1yr
Standard Case
AF
FF
CF
CFnd
CFnw
£'000
300
250
200
150
100
50
0
-50
-100
-150
-200
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

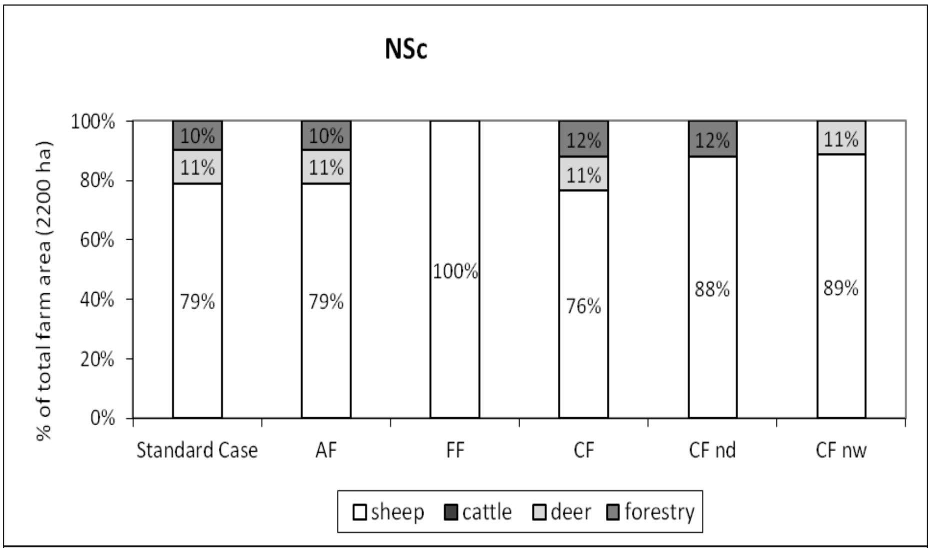

MCCb
Standard Case
AF
FF
CF
CFnd
CFnw
£'000
200
150
100
50
0
-50
-100
SFP
LFASS
Cow output
Sheep output
Deer output
Forestry income
Machinery costs
Rent/buildings costs
Variable costs
Labour costs
Final FBI

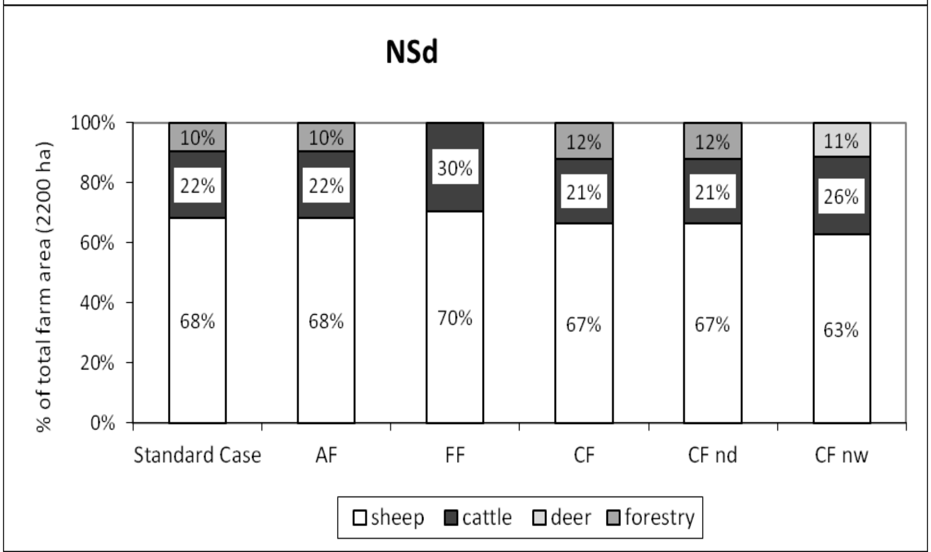
IX.4. Land Use for all profiles and all scenarios

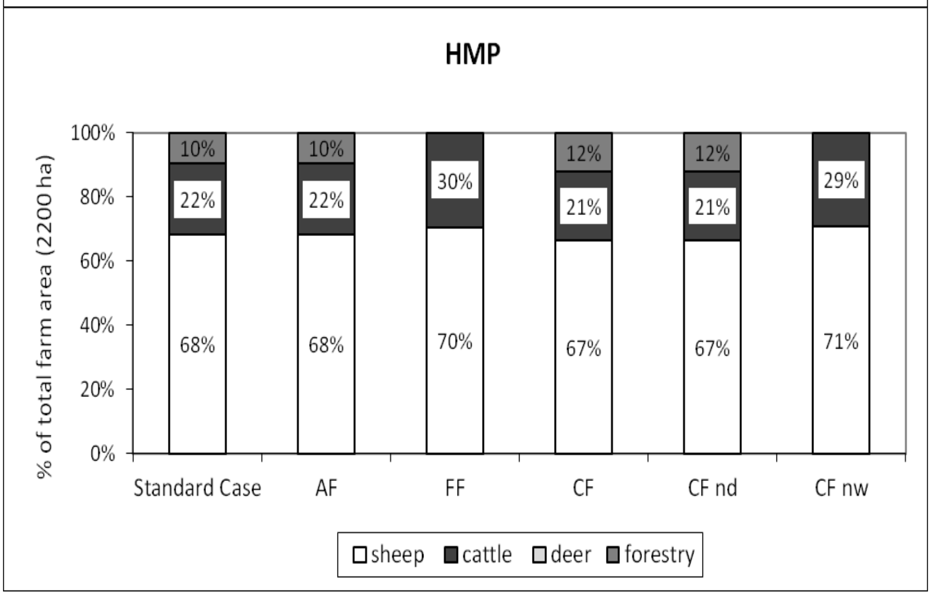


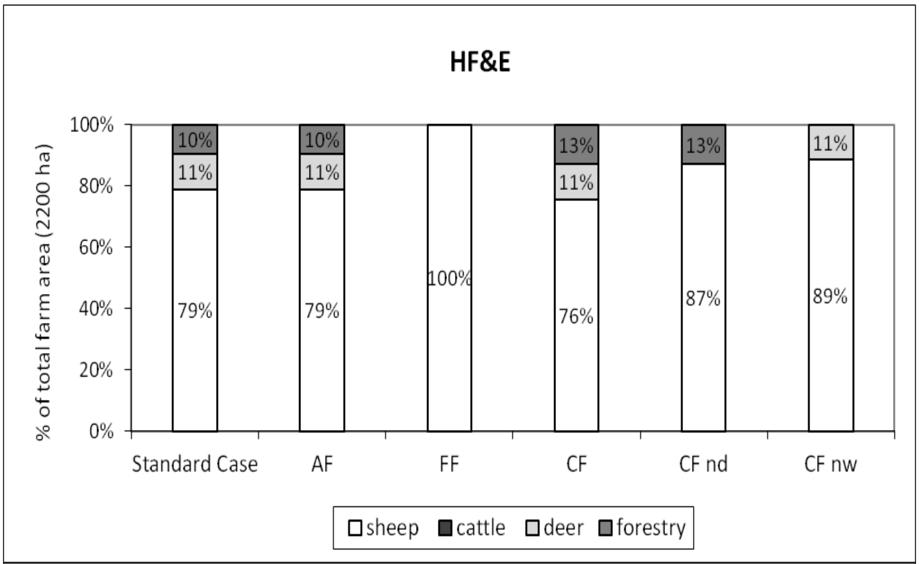


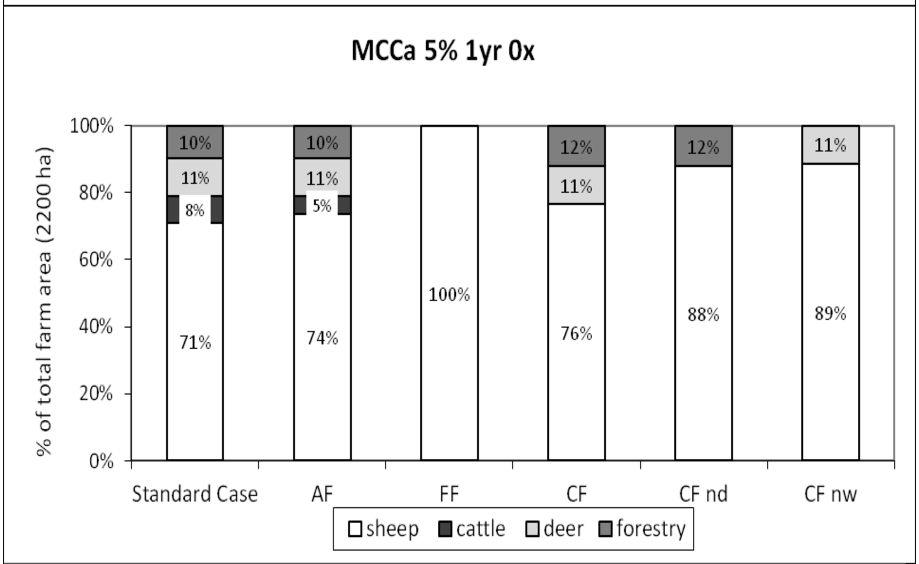


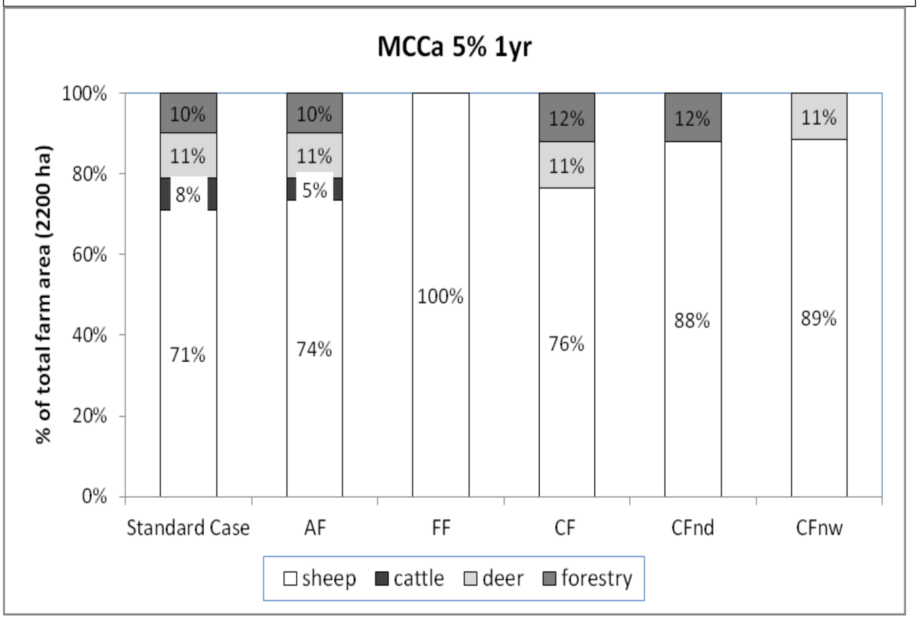

NSc
% of total farm area (2200 ha)
100%
80%
60%
40%
20%
0%
Standard Case
AF
FF
CF
CF nd
CF nw
10%
11%
79%
10%
11%
79%
100%
12%
11%
76%
12%
88%
11%
89%
sheep
cattle
deer
forestry

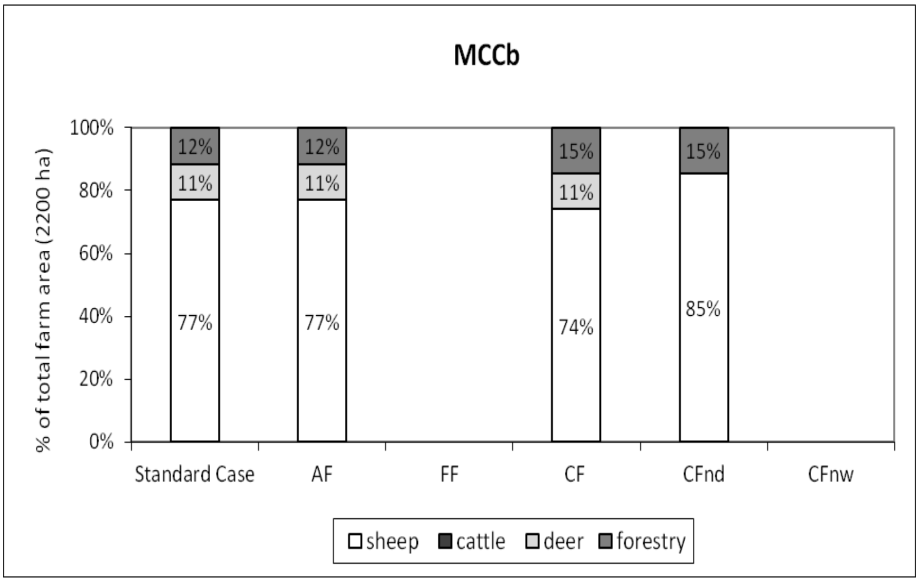

NSd
% of total farm area (2200 ha)
100%
80%
60%
40%
20%
0%
Standard Case
AF
FF
CF
CF nd
CF nw
10%
22%
68%
10%
22%
68%
30%
70%
12%
21%
67%
12%
21%
67%
11%
26%
63%
sheep
cattle
deer
forestry


HMP
% of total farm area (2200 ha)
100%
80%
60%
40%
20%
0%
Standard Case
AF
FF
CF
CF nd
CF nw
10%
22%
68%
10%
22%
68%
30%
70%
12%
21%
67%
12%
21%
67%
29%
71%
sheep
cattle
deer
forestry


HF&E
% of total farm area (2200 ha)
100%
80%
60%
40%
20%
0%
10%
11%
79%
10%
11%
79%
100%
13%
11%
76%
13%
87%
11%
89%
Standard Case
AF
FF
CF
CF nd
CF nw
sheep
cattle
deer
forestry


MCCa 5% 1yr 0x
% of total farm area (2200 ha)
100%
80%
60%
40%
20%
0%
10%
11%
8%
71%
10%
11%
5%
74%
100%
12%
11%
76%
12%
88%
11%
89%
Standard Case
AF
FF
CF
CF nd
CF nw
sheep
cattle
deer
forestry


MCCa 5% 1yr
% of total farm area (2200 ha)
100%
80%
60%
40%
20%
0%
10%
11%
8%
71%
10%
11%
5%
74%
100%
12%
11%
76%
12%
88%
11%
89%
Standard Case
AF
FF
CF
CFnd
CFnw
sheep
cattle
deer
forestry


MCCb
% of total farm area (2200 ha)
100%
80%
60%
40%
20%
0%
12%
11%
77%
12%
11%
77%
15%
11%
74%
15%
85%
Standard Case
AF
FF
CF
CFnd
CFnw
sheep
cattle
deer
forestry

APPENDIX X

Printout of published papers

Claire Morgan-Davies, Tony Waterhouse (2010) Future of the hills of Scotland: Stakeholders' preferences for policy priorities. Land Use Policy, 27. 387–398

Claire Morgan-Davies, Tony Waterhouse, Ron Wilson (2012) Characterisation of farmers' responses to policy reforms in Scottish hill farming areas. Small Ruminant Research, 102. 96– 107

Land Use Policy 27 (2010) 387–398

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Future of the hills of Scotland: Stakeholders' preferences for policy priorities

Claire Morgan-Davies*, Tony Waterhouse

SAC Research, Sustainable Livestock Systems, West Mains Road, Edinburgh, EH9 3JG Scotland, UK

ARTICLE INFO

Article history:
Received 23 July 2008
Received in revised form 6 May 2009
Accepted 10 May 2009

Keywords:
Adaptive conjoint analysis
Stakeholders
Hill
Upland
Land use
Preference
Policy

ABSTRACT

This paper sets out to assess stakeholders' preferences for policy priorities for the management of the hill areas of Scotland, using an adaptive conjoint analysis (ACA) method. The method is used to evaluate trade-offs that stakeholders make between policy priorities. A pre-survey was carried out to obtain a large number of defining characteristics of a Scottish hill land system, which were subsequently narrowed down to 20 attributes. A survey was implemented, where a range of stakeholders, who had an interest in the hill and upland areas of Scotland, were asked to select and rank five attributes (out of the 20) that, for them, best described a hill system. They were also asked to describe what constituted both good and poor levels for each of their 5 chosen attributes. A computerised ACA questionnaire was designed, using attributes and levels defined from the previous surveys. Respondents were asked what the policy targets for management choices and options should be in the next 10 years for the Scottish hill areas. Policy simulations were subsequently carried out using the ACA software, to compare stakeholders' actual preferences with seven different policy profiles, designed to reflect current land use issues and orientations for the Scottish hills.

Findings from the surveys showed the complexity of defining a hill system with a list of specific attributes. The ACA demonstrated that, despite differences between interest group of respondents, livestock was seen to be the most important attribute of a hill system that future policies should target. A local economy based on activities linked to the land was also highly preferred. Differences between respondents reinforced the fact that different interest groups, with different agendas, have views in conflict with others on certain issues. These emphasised how difficult it can be for policy makers to propose rural, environmental and land use policies that suit everybody.

The policy simulation showed that policy profiles focussed on biodiversity and tourism matched the preferences of stakeholders more than policy profiles for forestry and wild land. This demonstrated that trade-offs are necessary when formulating policies and that policy profiles based on a mixture of objectives are preferable to more singular ones. Some of the shortcomings of the methodology, particularly regarding the composition of respondents, are discussed. We conclude by suggesting that the ACA could be a useful tool to explore and evaluate future land use policies, especially in the context of a singular issue or conflict.

Introduction

In Scotland, 85% of the agricultural land has been given Less Favoured Areas status under European legislation (LFA - Article 2 of EU Council Directive No. 75/268/EEC). Within these areas, 75% of the land is classified as rough grazing, with unimproved or semi-natural vegetation and can be called "hill areas". Traditionally, the land use in these hill areas has been based on extensive hill sheep and cattle farming for food and wool production, often in association with differing levels of intensity of game management. These hill farming systems rely heavily on away-wintering and on imported concentrated feed to supplement the diet of the animals in winter (Scottish Natural Heritage, 2002). The main output is the production of store lambs, suckled calves and store cattle for lowland fattening, as well as older draft ewes for cross-breeding at lower altitudes. This is the core of the stratified production system, with upland and lowland farmers taking livestock from the hills (Dewar-Durie, 2000). Waterhouse (1996) found in his research that these systems were critical to the economic sustainability of the hill areas; more recently, the Royal Society of Edinbugh (2008) and the National Farmers' Union of Scotland (2008) also put emphasis on the importance of livestock farming in the hills. Forestry is another major land use for the hill areas of Scotland. At present, forest and woodland covers 17% of Scotland's land area, with a proposed increase to 25% by 2050 (Forestry Commission, 2008a). Game management

* Corresponding author. Tel.: +44 1838 400210; fax: +44 1838 400248.
E-mail address: claire.morgan-davies@sac.ac.uk (C. Morgan-Davies).

0264-8377/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.landusepol.2009.05.002

(grouse or deer) on sporting estates also represents a significant land use in these areas (MacGregor and Stockdale, 1994; PACEC, 2006).

A hill system, in this context, could be defined as an area of hill, mountain or moorland, with multiple land uses. Conflicts often exist between multifunctional land uses and such hill systems are no exception, as recently described by a Royal Society of Edinburgh (2008) report. Forestry and hill farming are rarely considered as integrated land uses (Morgan-Davies et al., 2008) and often, one is implemented to the detriment of the other. Conflicts between the sporting industry and agriculture are also well documented (e.g. MacMillan and Phillip, 2008). Many hill areas have also been designated for their international importance for nature conservation (Thompson et al., 1995) and in this context, conflicts between the different stakeholders regarding the management, use and function of the land, are likely to erupt. Studies by Visser et al. (2007) of disagreements between farmers and conservationists over the management of turloughs (seasonal wetlands and lakes) in Ireland concluded that such conflicts are inherent in the management of any habitats with high nature value.

Multifunctional land uses and conflicts can make the formulation of land use policies for these areas quite challenging, with potential perverse effects. One of the main land use policies for these areas has been the European Common Agricultural Policy framework. For instance, hill farms in Scotland, in common with other farms, were eligible for production subsidies in the past. Additional support for being in the LFA was formerly differentiated through Hill Livestock Compensatory Allowances (HLCA) which gave higher payments for hill farms over upland farms (Morgan-Davies et al., 2006a; Royal Society of Edinburgh, 2008). The HLCA was replaced by the Less Favoured Area Support Scheme (LFASS) in 2001. The combination of production subsidies of Sheep Annual Premium and Suckler Cow Premium and the HLCA/LFASS has subsequently made hill farming in the hill areas heavily dependent on agricultural and environmental schemes. However, the most recent dramatic change has been the recent reform of the Common Agricultural Policy in 2005, which decoupled subsidies from production and introduced a Single Farm Payment, subject to cross-compliance (Scottish Executive, 2003). Following these policy reforms, the management of farms in hill areas has undergone substantial changes, with animal numbers declining sharply in some areas with consequences for the vegetation and for economic activity (SAC Rural Policy Centre, 2008).

However, a much wider range of priorities for hill systems in Scotland has also started to emerge, making the formulation of policies even more challenging. For some stakeholders, food production and farming are still the core objectives (National Farmers' Union Scotland, 2007; Quality Meat Scotland, 2007). Forestry is now considered important for biodiversity and recreation, as well as for timber production (Woodland Trust Scotland, 2002; Forestry Commission, 2006), and is now a major part of Scotland's action to meet climate commitments (Forestry Commission, 2008a). In addition, tourism, access and sporting interests are major facets of hill systems (VisitScotland, 2007; Ramblers' Association, 2008; The Mountaineering Council of Scotland, 2008; BASC, 2008). Nature conservation and enhancement are also prevailing priorities (Scottish Natural Heritage, 2000). Finally, water management, the generation of renewable energy and, most recently, carbon management are emerging policy objectives for these areas. The two Scottish National Parks have attempted to encourage a combination of these priorities (Cairngorms National Park Authorities, 2005; Loch Lomond and the Trossachs National Park Authorities, 2007). Given this multitude of policies, orientations and objectives for the hill areas in Scotland, it is legitimate for land managers and policy makers to ask what should the hill systems deliver, to satisfy the views of stakeholders.

One of the difficulties lies in determining the appropriate method to use in order to elicit people's preferences for different land use functions. Consultation is one of the methods that could be used, as shown by Walker (2001) for river catchment management in Scotland. Bishop and Layton (1997) in the USA also commended the use of stakeholder consultation during the process of planning new parks. Similarly, Soliva et al. (2008) stated that "research that takes into account the views of local stakeholders has the potential to give a voice to those who are directly affected by political and administrative decisions, and whose daily actions shape and maintain mountain areas". Patel et al. (2007) recommended including "actors not normally considered as 'experts' but who possess equally valid and valuable knowledge and perspectives of the realities of the problems affecting their regions". In Scotland, Morgan-Davies et al. (2006a) used a participatory approach with stakeholders regarding potential conflicts for land use management.

Moreover, as shown by Ledoux et al. (2000), the use of participatory approaches and instruments adapted to enable a "trading-off" approach could also be very beneficial. Likewise, Ananda and Herath (2003), in the context of forest management in Australia, showed that whilst various participatory tools are used to consult and obtain inputs from stakeholders and communities, they fail to quantify the trade-offs that people make. They consequently recommended "the value functions approach to incorporate value preferences effectively into the decision making process". Horst and Gimona (2006) drew attention to the trade-offs of the various functions associated with woodlands, whilst Groot (2006) proposed a framework to take fully into account the ecological, socio-cultural and economic values of the landscape. In his approach, he advocated: (1) a function analysis, which translated ecological complexity into a limited number of landscape functions; (2) a function valuation, which included ecological, socio-cultural and economic valuation methods; and (3) a conflict analysis. Müller and Schmitz (2002) and Hillert et al. (2004) described similar framework approaches to measure preferences for landscape functions in Germany, using an adaptive conjoint analysis (ACA) method. Valeeva et al. (2005) also used an ACA method to investigate food safety within the dairy chain, as did van Schaik et al. (1998), to study the perceived risk factors of introducing disease onto farms. The ACA is based on the principles of conjoint analysis, which were originally used in marketing research for the elicitation of consumer preferences (Green and Srinivasan, 1990). In this context, it was considered an appropriate technique to elicit opinions from a range of stakeholders who live, work or have an interest in the hills and upland areas of Scotland.

The aim of this paper is therefore to describe the use of an adaptive conjoint analysis (ACA) to assess the hill systems of Scotland, as an aid to help understand and quantify: (1) what these systems should deliver, (2) how rural, environmental or land use policies should be prioritised, as seen by stakeholders and finally, (3) to see if such a method could be a useful tool for formulating land use policies in the future.

Methods

Participatory approach

A computerised adaptive conjoint analysis questionnaire allows participants to work with a large number of attributes for a given system and assesses the participants' preferences for these attributes. The questionnaire is automatically customised so that

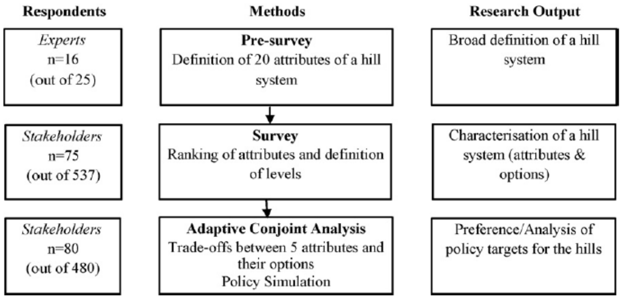


Fig. 1. Overview of the methodology (respondents, methods and research outputs).

each respondent is asked in detail only about those attributes that are of greatest relevance to them. Any given system has specific levels (or options) of attributes. A respondent's preference for any system is modelled as the sum of their preferences for each of the attribute options (van Schaik et al., 1998). A key issue with the methodology is therefore to obtain meaningful attributes and options to describe any given system.

In this paper, we used a methodology based on the methods described by Müller and Schmitz (2002). Fig. 1 summarises the approach. The hill system is first described through a list of broad definitions (Pre-survey). These broad definitions are then ranked and defined in more detail, to form a list of attributes and options for a hill system (Survey). Finally, the adaptive conjoint analysis is designed using the most important attributes and options, to assess the preferences of the stakeholders.

Pre-survey

Twenty-five experts (scientists and rural advisers) working in the upland and hill areas were contacted by electronic mail. The scientists included ecologists, economists, welfare and livestock specialists. The advisers were agricultural, environmental and forestry consultants and rural veterinary investigation officers; they represented a broad range of rural activities linked to the land. They were asked to "*draw-up a list of the attributes that you consider would best describe a hill system*". In total, 332 words and short descriptions were collected and sorted into 53 descriptions. These descriptions were further reduced into 20 broad attributes, designed to best reflect the respondents' answers.

Survey

When designing an ACA, the higher the number of attributes, the higher the number of combinations and the time necessary to complete the questionnaire. Consequently, it was decided to reduce the initial number of 20 attributes down to five. It was also imperative to define the options of each attribute. The survey was used for these two purposes.

A full postal and electronic survey was carried out in 2006, to identify the five main attributes of a hill system and to define their options, as seen by local stakeholders. A total of 537 people was contacted, including farmers, other land managers such as estate managers, veterinary investigation officers, rural agents, conservation scientists and managers, researchers and consultants, who were actively involved in or lived in the hills and uplands of Scotland. After a few background questions, they were asked to select and rank 5 attributes (out of the 20 given) that would best define a hill system. They were also asked to state what characterised a good and poor level for each of the 5 selected attributes. Ranking scores were calculated by weighting each ordinal number: 1 (best rank) was given 10 points, 2 was given 8, 3 was given 6, 4 was given 4 and 5 (last) was given 2 points. All the points were added together for each attribute, giving a total number of points for each. The highest total gave the highest rank. The resulting 20 ranked attributes are given in Table 1.

The subjective definitions of good and poor levels for the participants' chosen attributes were collected. The main recurrent themes were identified. Their compilations ultimately led to the definitions of options within each attribute in the ACA questionnaire.

The adaptive conjoint analysis was finally designed, using the Sawtooth Software SMRT version 4.7 (Sawtooth Software Inc., 2005).

Adaptive conjoint analysis (ACA)

The Sawtooth Software ACA questionnaire package provides respondents with a series of different computer screens. It starts with questions about ratings of options of single attributes, then preferences of one option of one attribute versus another option of another attribute, and moves onto preferences of combinations of attributes and options, with a final calibration exercise. The software estimates the preferences (utilities) for each single option of each attribute for the individual respondent. The relative

Table 1
Ranking scores of the attributes that best defined a hill system, as seen by respondents ($n = 75$).

Attributes	Ranking scores
Land use management	340
Landscape and Topography	276
Upland vegetation	180
Livestock management	178
Physical environment	176
Livestock	164
Woodland and Forestry	138
Farming products	126
Jobs and local employment	102
Access and Recreation	90
Game management	74
Socio-economic elements	74
Upland birds	74
Rurality and remoteness	58
Tourism	54
Wild mammals	38
Other categories	24
Invertebrates	16
Improved pastures	12
Built features	2

importance of each attribute is then derived for each individual by obtaining the difference between the utilities of the most preferred and least preferred attribute options, and expressed as a percentage. It thus becomes possible to assess the trade-offs made by respondents among multi-attributed systems. van Schaik et al. (1998) and Valeeva et al. (2005) explained in detail the principles behind this technique. In the current study, the ACA was used to address the question, "*What should the policy targets be in the next 10 years for the hill areas of Scotland*". In this context, policy targets were directly linked to the attributes and options of the hill system.

As alluded to, it was decided that it was necessary to reduce the initial number of attributes down to 5. Firstly, only the attributes with a ranking score above 100 were considered. Secondly, attributes which were of a similar nature (e.g. livestock and livestock management) were amalgamated. Additionally, "Landscape and Topography" and "Physical Environment" were not included in the ACA attributes, since it is difficult to influence these physical attributes by short-term policies. The options for each chosen attribute were designed using the information obtained in the survey, as explained above. Table 2 shows the final 5 attributes and their options. Game management and sporting issues were not included in the attributes because they were not ranked high enough by the respondents. Explanations about the meaning behind the attributes and options were provided in the ACA questionnaire. Two final questions asked about the profession and area of interest of the respondents.

A total of 480 people was asked to take part, either by mail or electronic mail. Most of the people contacted had previously been involved in the survey, and were people who were actively involved, interested in or lived in the hills and uplands of Scotland. Respondents who agreed to take part were sent a floppy disk or a CD containing the ACA questionnaire files. In some cases, we were able to send the ACA files by email.

Policy simulation

The ACA questionnaire assessed stakeholders' preferences for different policy targets for a hill system, based on their preferences of different attributes and options. Respondents were not asked to take into account costs and practicality of their policy preferences. However, it would be interesting to understand how the stakeholders' preferences compare to a series of profiles which relate to existing policy targets and orientations for the hills. Such comparison could be a useful tool to evaluate policies in time. The ACA software has a function called "market simulations" which allows such comparison. Within the software, a simulation transforms the calculated preferences into a useful model of projective market choices or share of preference for different products (in this case, for different policies). In other words, it uses the calculated respondents' preferences to estimate their likely preferences for hypothetical policy scenarios or profiles (Sawtooth Software Inc., 2003).

We created seven different policy profiles that we felt reflected different current land use issues in the hills. These profiles were established using a range of policy statements from different government agencies and NGOs. Where necessary, references from published research were also used. The sources for the statements are presented in Table 3. The seven profiles were: (1) Carbon Footprint, (2) Tourism, (3) Wild Land, (4) Livestock, (5) Forestry, (6) Biodiversity and (7) National Parks. We matched each of the profiles with the most appropriate options for each ACA attribute. In the end, each profile could be described as a specific combination of our attributes and options (see Table 3). In this way, it was possible to see how these profiles compared to our respondents' preferences, in terms of share (%) of preferences. Within the simulation software, a value was assigned to each option, to replace its original ordinal number. For example, the Livestock System options 1, 2 and 3 were given the respective arbitrary values of 11, 15 and 25. Within an attribute, when more than one option reflected a given policy profile, the average of the options' values was used. Indeed, the simulation tool did not allow more than one value for each attribute option. The values were chosen in such a way that, where possible, the average of the options' values was not the same as the value assigned to another independent option.

Table 2
List of the attributes and their options.

Attributes	Options
Land Use Management (LUM)	(1) Integrated, multiple objectives management closely linked to the characteristics of the land and people (2) Management focused on a high quality habitat supporting biodiversity objectives (3) Management focused on a single primary objective, which suits the land and the people
Vegetation (VC)	(1) Mosaic of indigenous vegetation communities in favourable condition (2) Managed heathland (3) Productive conifer plantation intended for timber (4) Un-managed landscapes and vegetation
Livestock system (LS)	(1) Combined sheep and cattle system—with low input/low output[a] (2) Cattle only—with low input/low output[a] (3) Sheep only—with low input/low output[a] (4) Combined sheep and cattle system—with high input/high output[a] (5) Sheep only—with high input/high output[a] (6) Cattle only—with high input/high output[a] (7) No livestock system
Farming products (FP)	(1) High level of output of good quality products for local markets or branded with local labelling for wider sales (2) Lower production of a lower quality product with no consideration of local or other market specifications, but with broad national or regional labelling (3) Products sold as a world-wide commodity (4) No direct products sold
Local economy (LE)	(1) Local economy with a few jobs from land management and more from rural tourism with some economic activity linked to the land[b] (2) Local economy with high levels of employment and economic activity linked to the land[b] (3) Local economy with negligible direct employment for land management and little economic activity linked to the land[b]

[a] For these 6 options, respondents were asked to consider choices between cattle or sheep or mixed systems, each option with differing levels of inputs and outputs and potentially differing levels of care by stock-workers. For the high input/high output systems the assumption to consider would include good levels of care, appropriate levels of nutrition and animal health system, all leading to high levels of output of saleable product—a generally intensive system even if using the resource extensively. For the low input/low output system, the assumptions would be an expectation of low levels of outputs, potentially labelled as a high quality product, with lower levels of inputs both of physical resources and of animal care—the livestock being more self-dependent in the low/low system and more dependent in the high/high.

[b] The contribution of the different sectors to rural employment, and to the use and supply of local services is complex. Here we provided respondents with three generalised scenarios. These might provide variation, for instance in the proportion of the rural houses outside settlements that are used by workers as opposed to holiday lets or older retirees or home-workers or the proportion of youngsters in local primary schools.

Table 3
Simulation policy profiles: attributes and options: statements and sources.

Profiles	Attribute/options	Justifying statements	Sources[a]
Carbon	LUM: 1,2,3	"land use sector [. . .] acts as carbon sink"	{a}, p. 39
Footprint	VC: 3	"forestry makes a net contribution to reducing CO_2"	{b}, p. 51
	LS: 1,2,3	"reduction in emissions through less intensive management practices"	{b}, p. 54
	FP: 1	"local marketing initiatives for energy efficiency"; "local timber processing which reduces timber miles"	{b}, p. 64; 53
	LE: 2	A greener Britain where a new green economy provides greater prosperity and high quality jobs even as it protects the environment and provides a better quality of life for all.	{c}, p. 1
Tourism	LUM: 1	Tourists prefer "more variety in the landscape"	{d}
	VC: 1,2	Tourists prefer "open moorland/hill land"	{d}
	LS: 1,2,3,4,5,6	Tourists prefer "fields, moorland, hill land with livestock grazing"	{d}
	FP: 1	"create a strong brand for Scotland"; "local marketing"; "authenticity"	{e}, p. 12; 15; 38
	LE: 1	"maximise the benefit of tourism in Scotland"	{e}, p. 34
Wild Land	LUM: 2	"manage places to enhance their wild attributes"	{f}, p. 17, 14
	VC: 4	"vegetation should consist of species which should be present naturally"	
		"allow natural processes to become dominant again"	{f}, p. 14
	LS: 7	"stopping certain human activities, [. . .], particularly sheep farming"	{f}, p. 17
	FP: 4	follows on from LS option 7 and VC option 4.	
	LE: 3	"policy of minimal outward promotion of these areas as recreational destinations" and follows on LS option 7	{f}, p. 17
Livestock	LUM: 3	"we want a prosperous and sustainable farming industry"	{g}, p. 1
	VC: 1,2	Follows on the obvious requirement for livestock	
	LS: 1,2,3,4,5,6	"helping to create a cost-effective and productive [. . .] industry."	{h}, p. 1
	FP: 1	"create an environment to increase demand for branded Scottish products"	{h}, p. 7
	LE: 2	"particularly in the uplands, grazing livestock are a key component in the rural economy"	{i}, p. 8
Forestry	LUM: 1	"ensure that the planned development of woodlands enhances the integration of forestry with other land uses"	{j}, p. 9
	VC: 3	"promote the production of fit for purpose timber"	{j}, p. 4
	LS: 7	"grazing in farmland premium supported woodland will not be allowed"; "stock fencing in establishing forests"	{k}, p. 7.4; 2.4
	FP: 1,2	"support the development of products [. . .] which increase the utilisation of home grown timber"	{j}, p. 4
		"FSC label is now [. . .] used on UK-grown forest products	{l}, p. 11
	LE: 1,2	"rural development: forestry should make a significant contribution"; "develop the contribution of woodlands [. . .] to the growth of tourism"	{j}, p. 5; 4
Biodiversity	LUM: 2	"enhancing Scotland's biodiversity"	{m}, p. 6
	VC: 1	"providing a mixture of woodland, blanket bog, moorland and upland pasture habitat"	{n}, p. 5
	LS: 1,2	"reducing grazing intensity"; "summer cattle grazing" is only hill livestock option in SRDP	{n}, p. 5; {g}, p. 76
	FP: 1	"encourage development of high value, place-linked products such as food from special farming systems"	{n}, p. 7
	LE: 1,2	"upland's economic [. . .] developed to couple wildlife & landscape enhancement to revenue-generating activities"	{n}, p. 7
		"enhance [. . .] tourism"	{m}, p. 22
		"to encourage [moorland] management that sustains and enhances economic prosperity & sustainable communities"	{o}, p. 1
National Parks	LUM: 1	"National Parks were introduced in Scotland to ensure a more integrated approach to the management of areas"	{q}, p. 2
	VC: 1,2,3	"well managed and conserved [. . .] environments supporting a wealth of biodiversity and healthy network of habitats"; "woodlands and forests [. . .] make an important contribution to the Park"	{p}, p. 22; {q}, p. 23
	LS: 1,2,3,4,5,6	"the Park Authority [. . .] will work with farmers [. . .] to help the long-term viability of farming in the Park"	{p}, p. 50
	FP: 1	"3 Year Milestone: Park Brand in place"; "promote a brand identity"	{p}, p. 9; {q}, p. 140
	LE: 1,2	"support and stimulate economic and social development within the Park that sustains and is sustained by its special natural and cultural values", "increase value of sustainable tourism", "stronger and more diverse economic opportunities", "healthy local economy"	{p}, p. 3, 4, {q}, p. 12

[a] Sources: {a} Scottish Government (2008); {b} Scottish Executive (2006a); {c} HM Government (2008); {d} Morgan-Davies et al. (2003); {e} VisitScotland (2007); {f} Scottish Wild Land Group (2002); {g} Scottish Executive (2006b); {h} Quality Meat Scotland (2007); {i} National Farmers' Union (2007); {j} Forestry Commission (2005a); {k} Forestry Commission (2005b); {l} Forestry Commission (2004); {m} Scottish Natural Heritage (2008); {n} RSPB (2007); {o} Scotland's Moorland Forum (2008); {p} Cairngorms National Park Authorities (2005); {q} Loch Lomond and the Trossachs National Park Authorities (2007).

Analysis

Pre-survey and survey

A method for analysing focus group answers (Royal National Institute for the Blind, 1999; Millward, 2006) was used to collate, sort and compile the pre-survey attributes into the final list of 20. The same method was used to compile the attribute options from the results obtained in the survey. Correlation analysis and non-parametric tests (Genstat statistical software, VSN International Ltd, 2005) were used to analyse the way the survey respondents chose and ranked the characteristics. This has also been described in a previous paper by Morgan-Davies et al. (2006b).

Adaptive conjoint analysis

The consistency of the answers of each respondent was checked using correlation coefficients provided by the ACA software. It calculated correlations between the calculated preferences for each attribute option, for each respondent. Two respondents with low correlation indicating a high level of inconsistency were subsequently discarded and the remaining respondents all displayed correlation coefficients greater than 0.64.

Using the Genstat statistical package (VSN International Ltd, 2005), a Linear Mixed Model (REML) was used to examine whether the relative importance (expressed as a percentage ratio) of the policy priority of each attribute was dependent on the profession and/or area of interest of the respondents.

Within each attribute option, analyses of variance (ANOVA) were carried out on the utility points obtained in the ACA questionnaire for each respondent, to investigate whether or not their answers varied according to their profession and/or area of interest.

The simulation results were analysed using a Linear Mixed Model (REML) to examine the effect of the respondents' profession and/or area of interest on their preferences for different policy profiles.

Results

Pre-survey and survey

Sixteen experts responded to the pre-survey, providing a wide range of definitions and attributes of a hill system. When grouping the information, the most mentioned categories were plant types, animal types, human elements, physical environment, socio-economic elements, Topography and Landscape and land use. This information was collated and sorted into 20 main attributes, which were used in the survey (see Table 1).

Seventy-five people answered the survey, giving a response rate of 14%. The respondents were farmers (20%), NGO/agencies (19%), scientists (16%), rural agents/nature conservation officers (12%), agricultural advisers (11%), conservation land managers (7%), policy advisers (7%), veterinary investigation officers (5%) and commercial land managers (4%). Correlation analysis between the choices of the different respondent groups showed that scientists' choices were highly similar to those of rural agents ($r^2 = 0.79$), agricultural advisers ($r^2 = 0.77$) and NGO/agencies ($r^2 = 0.64$). Agricultural advisers and NGO/agencies also chose their attributes similarly ($r^2 = 0.64$). Interestingly, the choices made by the farmers were not strongly correlated with any other group.

The ranking of the main attributes is presented in Table 1. Non-parametric tests (Mann-Whitney U and Wilcoxon rank-sum tests) were used to analyse the way respondents ranked their attributes. They showed that farmers ranked their chosen attributes in a similar manner to that of the agricultural advisers, NGO/agencies and scientists ($P < 0.05$). However, farmers were different from commercial land managers, conservation land managers, veterinary investigation officers and rural agents/nature conservation officers.

ACA questionnaire

Out of 480 people contacted, 134 agreed to have the ACA sent to them. Of them, 60% completed the ACA questionnaire.

All respondents

The relative importance of each attribute, using data from all respondents, is shown in Table 4, as well as respondents' preferences for each option within each attribute (expressed as zero-centred differences). Although all five attributes were considered important to the respondents (range: 17.0% to 22.9%), farming products and livestock system had the two highest values. Since the initial question related to policy targets, this shows that these two attributes were considered as the two most important policy targets for the hills. Table 5 shows the most preferred and the least preferred combination of the attribute options using data from all respondents.

Table 4
The relative importance (in %) of the policy priority of each attribute for all respondents and the zero-centred differences of each option for all respondents.

Attributes and options	Zero-centred differences	Average attribute importance (%)
Land Use Management		
Option 1	29.9	17.0
Option 2	10.0	
Option 3	−39.9	
Vegetation cover		
Option 1	39.5	18.3
Option 2	5.5	
Option 3	−22.3	
Option 4	−22.6	
Livestock System		
Option 1	37.8	22.9
Option 2	6.9	
Option 3	3.7	
Option 4	11.4	
Option 5	−12.2	
Option 6	−5.5	
Option 7	−42.1	
Farming Products		
Option 1	56.8	21.1
Option 2	−12.9	
Option 3	−4.5	
Option 4	−39.5	
Local Economy		
Option 1	13.6	20.7
Option 2	39.9	
Option 3	−53.5	

Within respondents' groups

Fig. 2 shows the number of respondents according to both their profession and area of interest. The two biggest profession groups were researchers/scientists ($n = 18$ respondents, 23%) and NGO/Government policy officers ($n = 18$, 23%). Researchers ranged from animal scientists, ecologists, welfare specialists, upland farming specialists and land economists. The NGO/Government policy officers group had respondents from local Scottish councils, Scottish Natural Heritage, Scottish National Parks, Forestry Commission and Royal Society for Protection of Birds. The farmers were the third largest group ($n = 14$, 18%), followed closely by the commercial land use consultants/advisers ($n = 12$, 15%). The latter were mainly agricultural, conservation and forestry consultants. When asked to choose their single main area of interest relative to the hills of Scotland, the individuals of these profession groups chose a broad range of interests. For instance, researchers/scientists were interested in livestock production, nature conservation, forestry, animal care and welfare and rural communities.

Results of the Linear Mixed Model (REML) on the relative importance of the policy priority of each attribute, according to respondents' profession and area of interest, are shown in Table 6. All respondents had similar levels of agreement on the relative importance of Land Use Management, Local Economy and Livestock System attributes. However, the attributes of Vegetation Cover and Farming Products differentiated respondents by area of interest (as

Table 5
Most and Least preferred combinations of attribute options (policy priorities) for the hills, as seen by the stakeholders.

	Options	
Attributes	Most preferred	Least preferred
Land Use Management	Integrated, multiple objectives management closely linked to the characteristics of the land and people	Management focused on a single primary objective, which suits the land and people.
Vegetation Cover	Mosaic of indigenous vegetation communities in favourable condition	Un-managed landscapes and vegetation
Livestock System	Combined sheep and cattle system with low input/low output	No livestock system
Farming Products	High level of output of good quality products with local labelling for wider sales	No direct products sold for local markets or branded
Local Economy	Local economy with high levels of employment and economic activity linked to the land	Local economy with negligible direct employment for land management and little economic activity linked to the land

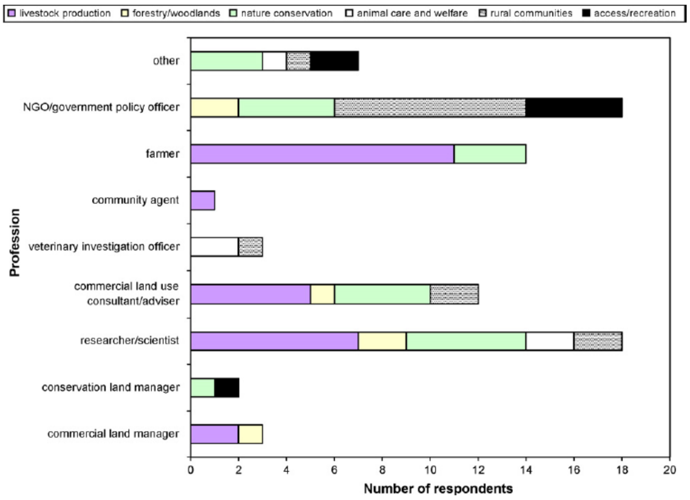


Fig. 2. Profession and area of interest of the ACA respondents (the profession "others" was one of the options offered).

seen in Fig. 3). Both the Nature Conservation and Access/Recreation groups prioritised Vegetation Cover as the most important attribute for policy support in hill systems. In contrast with other groups, the Access/Recreation group saw Farming Products as the least important attribute of a hill system.

At the options level (Table 7, ANOVA results), there was a general consensus amongst the respondents on the Local Economy options, with a preference for option 2 ("high levels of employment and economic activity linked to the land"). However, there were differences regarding the other four attributes, according to the respondents' area of interest. For example, the Access/Recreation interest group preferred a land use management focussed on high quality habitat supporting biodiversity objectives (LUM option 2), with a mosaic of indigenous vegetation (VC option 1). The Nature Conservation interest group had a similar vision for these two attributes. However, they were in disagreement with the Livestock Production interest group, who preferred Livestock System option 4 (combined sheep and cattle with high inputs and high outputs). This option can be misleading. As explained in Table 2, the option of the high input/high output system meant good levels of care, appropriate levels of nutrition and animal health, perhaps with more on-farm labour at key events; all leading to higher levels of saleable output (such as higher number of twins or crossbred young animals). Therefore such system could be seen as generally intensive even if the resource was used extensively. This option was never meant to be viewed as a 'classic' intensive lowland system.

Finally, the Animal Care and Welfare interest group most favoured Livestock System option 5, whereas the Woodland/Forestry interest group did not.

Table 6
Significance of the effects of the respondents' profession and area of interest on the relative importance of policy priority of each attribute, resulting from the REML analysis (statistical differences: * significant; ** highly significant).

	P value	
Attributes	Profession	Area of interest
Land Use Management	0.331	0.304
Vegetation Cover	0.417	0.003**
Livestock System	0.582	0.566
Farming Products	0.206	0.037*
Local Economy	0.944	0.615

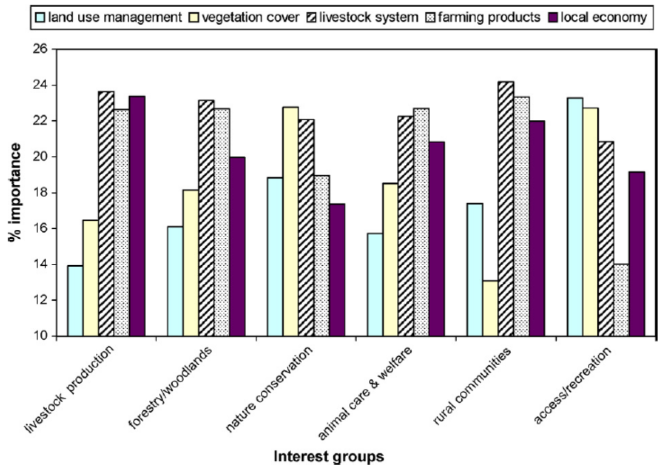


Fig. 3. Relative importance of policy priorities for each attribute, by interest groups.

Policy simulation

Results showed that out of the 7 created policy profiles, the "Biodiversity" profile best fitted (33.5%, ±1.2) the individual scores of the respondents (Table 8). This indicates that policy targets, based around the attributes and options that are most closely linked to the Biodiversity policy statements used, is the best match to the preferences of the stakeholders in this study. The Tourism profile was the next best fit to the individual scores of the respondents (18.2%, ±1.6), although it was much lower. The Livestock, Carbon Footprint and National Parks profiles were quite similar, with respective shares of stakeholders' preferences of between 11% and 15%. The Wild Land and Forestry policy profiles did not match with the policy preferences of the respondents (2.6%, ±0.4 and 5.4%, ±0.7, respectively).

Table 7
Results of a one-way ANOVA, showing the effect of respondents' interests on the options of each attribute (*P* value), the average utilities points for each option and rank (in brackets, 1 being best) of each option, by interest groups (statistical differences: * significant; ** highly significant; *** very highly significant; NS non significant).

Attribute options	*P* value	Average utility points (and rank) per interest group					
		Livestock production	Forestry/woodlands	Nature conservation	Animal care and welfare	Rural communities	Access/recreation
Land Use							
Option 1	NS	31.7 (1)	23.8 (1)	24.6 (2)	30.7 (1)	37.3 (1)	27.6 (2)
Option 2	0.008**	−7.4 (2)	4.5 (2)	29.2 (1)	13.6 (2)	2.5 (2)	36.9 (1)
Option 3	NS	−24.3 (3)	−28.3 (3)	−53.8 (3)	−44.3 (3)	−39.8 (3)	−64.4 (3)
Vegetation Cover							
Option 1	<0.001***	34.0 (1)	19.5 (1)	59.9 (1)	35.1 (1)	20.6 (1)	59.8 (1)
Option 2	0.020*	14.1 (2)	−23.1 (4)	3.2 (2)	2.1 (2)	8.2 (2)	1.5 (2)
Option 3	0.043*	−22.8 (3)	11.3 (2)	−38.0 (4)	−10.4 (3)	−7.9 (3)	−42.0 (3)
Option 4	NS	−25.3 (4)	−7.7 (3)	−25.0 (3)	−26.8 (4)	−20.9 (4)	−19.3 (4)
Livestock System							
Option 1	NS	39.1 (1)	59.2 (1)	40.9 (1)	−1.7 (5)	34.6 (1)	40.9 (1)
Option 2	NS	−2.0 (4)	10.5 (2)	22.3 (2)	−18.5 (6)	12.9 (3)	−0.8 (3)
Option 3	0.030*	3.3 (3)	−15.7 (6)	11.6 (3)	14.9 (4)	3.7 (4)	−8.5 (5)
Option 4	0.005**	27.3 (2)	−2.4 (3)	−12.5 (5)	18.9 (2)	16.4 (2)	16.9 (2)
Option 5	<0.001***	−4.5 (5)	−31.2 (7)	−19.6 (6)	26.1 (1)	−18.8 (6)	−18.1 (6)
Option 6	NS	−6.4 (6)	−11.6 (5)	−12.4 (4)	15.3 (3)	1.4 (5)	−5.6 (4)
Option 7	<0.001***	−56.8 (7)	−9.0 (4)	−30.3 (7)	−55.0 (7)	−50.2 (7)	−24.9 (7)
Farming Products							
Option 1	0.024*	60.9 (1)	64.1 (1)	50.5 (1)	63.0 (1)	63.7 (1)	35.8 (1)
Option 2	NS	−7.7 (3)	−6.3 (2)	−15.2 (3)	−15.6 (3)	−19.5 (3)	−15.9 (3)
Option 3	0.006**	−2.1 (2)	−30.1 (4)	0.7 (2)	−7.6 (2)	−7.0 (2)	1.0 (2)
Option 4	0.025*	−51.1 (4)	−27.7 (3)	−35.9 (4)	−39.8 (4)	−37.2 (4)	−20.9 (4)
Local Economy							
Option 1	NS	9.7 (2)	13.5 (2)	16.0 (2)	7.6 (2)	17.3 (2)	18.5 (2)
Option 2	NS	51.6 (1)	35.2 (1)	27.3 (1)	41.9 (1)	38.1 (1)	38.6 (1)
Option 3	NS	−61.3 (3)	−48.7 (3)	−43.3 (3)	−49.5 (3)	−55.4 (3)	−57.1 3)

Table 8
How policy profiles 'fit' stakeholders' preferences—in % preferences for all respondents and by interest groups (in bold are the best fit between stakeholders' groups and policy profiles, in italics are the worst fit).

Policy profiles	All respondents	Livestock Production	Forestry/Woodlands	Nature Conservation	Animal Care and Welfare	Rural Communities	Access/Recreation
Carbon Footprint	11.2	9.7	22.3	7.9	16.9	14.2	6.8
Tourism	18.2	17.7	14.5	18.1	**25.0**	19.3	16.3
Wild Land	*2.6*	*1.1*	*3.4*	*4.2*	*0.8*	*2.3*	*4.9*
Livestock	14.1	23.8	7.0	8.2	12.1	11.8	6.9
Forestry	5.4	3.9	12.7	4.5	6.9	5.7	5.9
Biodiversity	**33.5**	**24.5**	**30.7**	**48.0**	22.1	**26.6**	**50.4**
National Parks	14.9	19.3	9.4	9.1	16.3	20.1	8.9

There were statistical differences between the profession groups and area of interest groups in how well they matched the policy profiles. The Biodiversity policy profile best matched the policy preferences of the Conservation Land Managers profession group ($P = 0.018$); the Livestock policy profile best matched the preferences of the Farmers profession group ($P = 0.017$). The Forestry policy profile was more preferred by the Woodland/Forestry interest group ($P = 0.034$).

Discussion

Surveys

Defining hill systems proved to be quite a challenge, given the wide range of people living, using, studying or enjoying the land. It took more than 20 attributes to achieve a comprehensive description of what such a system represents.

Although most respondents in the survey agreed in their choices in attributes, some groups were set apart, as seen in the correlation analysis. Indeed, farmers were not well correlated to any other group and tended to choose predominantly livestock management and farming products as the defining attributes of a hill system. This probably reflected their primary involvement and showed that they still define themselves through their husbandry systems, as producers. Ranking of the attributes gave a different picture. Although farmers tended to rank attributes in the same way as the NGO/agencies, the scientists and the advisers, they were still set apart from the other major land users (commercial and conservation land managers) and rural representatives (rural agents/nature conservation officers). Landscape and Topography and Land Use Management attributes came up at the top of the ranking for all respondents. Physical Environment (i.e. soil, climate, slope, and accessibility) was also an aspect that was considered as very important. It could show that people understand the limitations or constraints that are unalterable, and the fact that any use of hill areas must work around these. Upland Vegetation, Livestock and Woodland/Forestry (primary production sources for these systems) were also high up in the ranking. Tourism and Access/Recreation were much lower in the ranking, which might show that these functions are not yet regarded as greatly important aspects in the definition of hill systems. This notion has also been found in the less favoured areas of Germany where landscape heritage was found to only be of medium importance to sustainable land use systems after water quality (Müller et al., 2001). However in France, for instance, rural tourism is viewed as a major economic sector, as described by Brinbaum and Guichard (1989).

Adaptive conjoint analysis

The ACA questionnaire assessed stakeholders' preferences for policy targets and support for a hill system, based on its attributes and options. The Livestock System attribute had the highest average importance for all respondents, whilst the Land Use Management attribute had the lowest. This is somewhat in contrast with the initial survey results and shows that looking at trade-offs can elicit different answers than simply choosing or ranking attributes. Although the ACA method does not allow the motivation of respondents to be understood, the results demonstrate that most stakeholders believe livestock has a role to play in a hill system. However, the actual trend for animal numbers (sheep and cattle) in the hill areas of Scotland is rapidly declining (SAC Rural Policy Centre, 2008). Consequently there could be a conflict between what is happening and what the respondents would favour. This would also depend on whether this decline is a move to 'low' outputs and numbers (which is favoured by quite a few groups) or a move to no livestock, which is the least favoured. Moreover, respondents also agreed that a 'local economy with high levels of employment and economic activity linked to the land' was the best option for policy support. Combining these two findings, we can deduce that our stakeholders thought that a livestock production and a local economy linked to the land activity are two factors that are important for the hills. This echoes results from France, where Buller and Brives (2000) found that French rurality could not be defined without the concept of agricultural production. However, the option which favoured tourism based jobs was not the least preferred. It shows that tourism and diversification were also options worthy of policy support. This reflects other situations, such as in Somerset, where a study by McInerney and Turner (1993) showed that 25% of farm holdings in the area had diversified. Likewise in Scotland, this trend of increasing diversification has been shown by Slee et al. (2001).

Finally, despite differences in their levels of rating, respondents thought that policy support should be given to deliver a specialised product (high quality, with local branding). This idea is partly recognised by the latest Forward Strategy for Scottish Agriculture, which identified the importance of product differentiation and aimed to promote local processing and marketing (Scottish Executive, 2006b). Likewise with the branding of Scotch beef and Scotch lamb, being recognised as Protected Geographical Indication (Quality Meat Scotland, 2006). Our findings thus highlight that there is probably scope for a more specific local market, at the local regional level, rather than at the national (Scotland or UK) level. Indeed, Lyon et al. (2003) already noted in their study the need at the UK level to reconnect food producers and local consumers and to restore consumer confidence.

The ACA questionnaire also allowed distinctions to be made between groups of respondents. Area of interest was the most differentiating factor. Some of the differences between interest groups were to be expected. Indeed, woodland policies and timber production are not closely related with issues regarding animal care and livestock production, hence their frequent opposition in stakeholder ratings. Although some recent policy changes regarding grazing in woodland (Forestry Commission, 2005c) have been made, this research shows that there is still a strong feeling that woodland and animal production are two very different issues. Likewise, some of the preferences of people interested in Nature Conservation or Access and Recreation were anticipated; for instance rating the vegetation cover attribute as very important. This relates well with strategies concerning the natural environment, such as the Scottish Natural Heritage strategy (Scottish Natural Heritage, 2003). The livestock system options created many differences between interest groups, with very strong views and ratings. Clearly the level of outputs in the sheep, cattle or combined systems seemed to have a very different meaning between each interest group. The Animal Care and Welfare group strongly preferred policy support for a sheep system with high input/high output. This might be because this group perceived that high inputs meant higher welfare inputs. Indeed, higher outputs can mean less mortality in both the adult and young animals (as shown by Morgan-Davies et al., 2008). However, when looking at all respondents, policy support for the combined system with low inputs/low outputs was the most preferred option. This underpins the debate about level of stocking and outputs from these livestock systems, as mentioned by Morgan-Davies et al. (2006a).

This research reinforced the fact that different interest groups, with different agendas, have conflicting opinions on certain issues. These disagreements re-emphasised how difficult it can be for policy makers to propose rural, environmental and land use policies that suit everybody.

Policy simulation

Whilst the ACA questionnaire was used to assess the trade-offs between policy targets, the subsequent simulation allowed a further exploration of current policies and orientations relating to the hill areas of Scotland. However, when we set about establishing the different policy profiles, it was difficult to establish the relevant attribute options. This was mainly because most statements available from agencies and organisations lacked specificity about those issues. It reinforced the complexity of defining a single vision for the hills. Nonetheless, such a simulation exercise was useful and highlighted which of the set policy profiles were not very popular with our range of stakeholders. For instance, the Wild Land profile was not favoured, bearing similarities with what Soliva et al. (2008) found in some European mountain communities (in France, Scotland, Norway, Switzerland, Greece and Slovakia). Likewise, the Forestry profile also scored low in the preferences of our stakeholders, highlighting a potential conflict with the actual policies and incentives for afforestation, which aim to achieve the Scottish Government's vision to have a further 50% increase to an overall 25% woodland cover by 2050 (Forestry Commission, 2008a). Both wild land and increases in tree cover have strong advocates in Scotland (Scottish Wild Land Group, 2002; Forestry Commission, 2008b) but is it interesting to see that these visions were poorly supported by our stakeholders, compared to others. Biodiversity and Tourism were the most preferred profiles, which in turn seem to be in line with actual trends in policy making and orientations (Scottish Government, 2008). This may also show that the respondents preferred policies based on a mix of different outcomes rather than policies focused on singular issues. This would support the idea of a multi-functional landscape for Scotland, linked to a mixed policy model (Royal Society of Edinburgh, 2008). The differences found between groups reflected once more the range of interests and professions and hence of policy choices within our respondents.

This methodology could potentially be very useful when understanding and formulating future land use policies. Nonetheless, some points need to be taken further into consideration in our approach.

First of all, some topics may appear to be missing. For instance, carbon storage, and wind and other renewable energy production methods were not included in the original set of attributes of a hill system. However, at the time of the pre-survey (early 2006), the respondents did not see these as importantly as they might be now.

Secondly, these results are respondent driven and the composition of respondents in this study had a large part to play. In the survey, farmers were the largest answering group (20%), whilst for the ACA questionnaire, they were in third position (15%), behind scientists and NGOs/policy officers. The surveys format might have influenced the respondents. The first survey was paper-based and did not require any specific equipment. The ACA questionnaire was computer-based and may have discouraged some of the potential farmers and land managers. Indeed, Warren (2002) reported a divide between UK farmers on the use of computers and Information Technology. This aspect should be taken into account if the ACA is to be used in the future as a method to assess all types of stakeholders. It could also be that the ACA method was focused on policy objectives whilst the survey was more descriptive. Farmers may have found the ACA more challenging to complete than the survey. Additionally, most scientists and NGOs/policy officers were intrigued by the use of the ACA to assess policy objectives, and this may have prompted them to take part in the study. It also relates to which groups are targeted when sending the surveys. Whilst the authors tried to contact a large number of stakeholders, and as varied as possible, there was always a bias and groups of respondents were not equal. However, even if these results only express the views of our samples of respondents, the differences between groups are relevant.

Finally, the policy profiles we created were based on the interpretation of existing policies and visions, which may not have fitted completely within our attributes and options. Indeed, some policies were close to some of our profiles, whilst others were not. Moreover, we considered the hill system as a whole. If we had a singular policy or a well defined conflict issue to consider, the method would have worked better. Nonetheless, this approach gave some insight into how new rural, land use or environmental policies and schemes might have to be drafted or prioritised to convey what the local stakeholders want from these hill systems. It could be a useful tool to consider in the future.

Conclusions

This work showed the complexity of hill systems and their outputs and of formulating policies for these environments. It demonstrated that there is not a single shared vision for policy support for the hill areas of Scotland. Overwhelmingly though, it showed that stakeholders in this study would prefer the rural, environmental and land use policy priorities to deliver a system in which livestock has a part to play. These views are echoed in Europe, where Nisbet et al. (2005) showed that sustaining farming practices is one area where consensus can be reached between a wide range of stakeholders. However, the actual policies and reforms in Scotland tend to accentuate a decline in livestock numbers and farm activity.

This study also suggests that more multi-objective and integrative schemes and policies would be needed if policy makers want to reflect people's preferences and opinions.

Finally, questions arise of how these ideal policy targets can be attained and how to communicate to and from government and agencies. In addition, the composition of respondent groups was a key point. It may also have been useful to contact urban stakeholders in this study (as Soliva et al. (2008) did in their research).

Nonetheless, the ACA questionnaire and simulation approach proved to be a useful tool to explore which future rural, environmental and land use policies are favoured, or less preferred, by a wide range of stakeholders involved in the hills and uplands of Scotland. Such a method of comparing a set of 'ideal' policy targets with existing policy orientations could still be beneficial in a wider land use policy setting context, even if working on a singular issue or conflict would be more effective.

Acknowledgements

SAC received financial funding from The Scottish Government Rural and Environment Research and Analysis Directorate. The authors also wish to thank the people who took the time to answer the various surveys in this research and the two anonymous reviewers for their valuable comments on the manuscript.

References

Ananda, J., Herath, G., 2003. Incorporating stakeholder values into forest planning: a value function approach. Ecological Economics 45, 75–90.

BASC, 2008. Constitution and objects. http://www.basc.org.uk/media/constitution.pdf.

Bishop, A., Layton, R., 1997. Crafting consensus on controversial parks. Parks and Recreation (Ashburn) 32, 38–47.

Brinbaum, D., Guichard, A., 1989. Why bet on rural tourism? Chambres d'Agriculture 768, 6.

Buller, H., Brives, H., 2000. France: farm production and rural product as key factors influencing agri-environmental policy. In: Buller, H., Wilson, G.A., Höll, A. (Eds.), Agri-Environmental Policy in the European Union. Ashgate Publishing Ltd, Aldershot, pp. 9–30.

Cairngorms National Park Authorities, 2005. Cairngorms National Park Corporate Plan 2005–2008. Cairngorms National Park Authorities, Grantown on Spey, 17 pp.

Dewar-Durie, A., 2000. The Scottish sheep industry: a way forward. Scottish Executive, Edinburg, website publication. http://www.scotland.gov.uk/Publications/2007/06/06110400/0.

Forestry Commission, 2004. The UK Forestry Standard—The Government's Approach to Sustainable Forestry. Forestry Commission, Edinburgh, 74 pp.

Forestry Commission, 2005a. Corporate Plan 2005–2008. Forestry Commission, Edinburgh, 25 pp.

Forestry Commission, 2005b. SFGS Applicant's Booklet, Section 7, Farmland Premium Scheme. Forestry Commission, Edinburgh, 8 pp.

Forestry Commission, 2005c. Woodland grazing—it's e-cow-logical! News release No: 7644.

Forestry Commission, 2006. The Scottish Forestry Strategy 2006. Scottish Executive, Edinburgh, 87 pp.

Forestry Commission, 2008a. The Scottish Forestry Strategy 2008-2011 – Implementation Plan and 2007-2008 Progress Report. Forestry Commission, Edinburgh, 49 pp.

Forestry Commission, 2008b. Climate change and the national forest estate, consultation on forestry provisions in the Scottish Climate Change Bill. Forestry Commission, Edinburgh, 7 pp.

Green, P.E., Srinivasan, V., 1990. Conjoint analysis in marketing: New developments with implications for research and practice. Journal of Marketing 54, 3–19.

Groot, R.d., 2006. Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. Landscape and Urban Planning 75, 175–186.

Hillert, D., Ahrens, H., Harth, M., Horlitz, T., Sander, A., 2004. Model-based policy in nature conservation: determining the "optimal" land use pattern in the agrarian landscape of the MAB biosphere reserve "Mittelere Elbe". Agrarwirtschaft 53, 131–141.

HM Government, 2008. Building a Low Carbon Economy—Unlocking Innovation and Skills. Defra publications, London, 40 pp.

Horst, D. van den, Gimona, A., 2006. Spatial heterogeneity in landscape multi-functionality: the challenges for forestry policy in Scotland. In: Wall, S. (Ed.), Small Scale Forestry and Rural Development: The Intersection of Ecosystems, Economics and Society. IUFRO, Galway, pp. 502–513.

Ledoux, L., Crooks, S., Jordan, A., Turner, R.K., 2000. Implementing EU biodiversity policy: UK experiences. Land Use Policy 17, 257–268.

Loch Lomond and the Trossachs National Park Authorities, 2007. Loch Lomond and the Trossachs National Park Plan 2007–2012. Loch Lomond and the Trossachs National Park Authorities, Balloch, 153 pp.

Lyon, P., Colquhoun, A., Janhonen-Abruquah, H., 2003. Consumer confidence and UK food retailing: why does local food matter? Journal of Food Agriculture and Environment 1, 12–21.

MacGregor, B.D., Stockdale, A., 1994. Land use change on Scottish Highland Estates. Journal of Rural Studies 10, 301–309.

MacMillan, D.C., Phillip, S., 2008. Consumptive and non-consumptive values of wild mammals in Britain. Mammal Review 38, 189–204.

McInerney, J., Turner, M., 1993. Agricultural Adjustment in West Somerset. Agricultural Economics Unit, University of Exeter, Exeter, 50 pp.

Millward, L.J., 2006. Focus Groups. In: Breakwell, G., Hammond, S., Fife-Shaw, C., Smith, J.A. (Eds.), Research Methods in Psychology, 3rd ed. Sage Publications, London, pp. 274–299.

Morgan-Davies, C., Waterhouse, A., Holland, J., Zografos, C., 2003. Assessing uptake of innovative hill land uses—retaining sheep alongside planting of new native woodlands. Scottish Forestry 57, 211–215.

Morgan-Davies, C., Waterhouse, A., Pollock, M.L., Smyth, K., 2006a. Local area farming plans—a common reality for farmers and conservationists in the Scottish Highlands. Scottish Geographical Journal 121, 385–400.

Morgan-Davies, C., Waterhouse, A., Umstatter, C., 2006b. Sustainable hill and upland systems—what do people want the hills to deliver? International Journal of Biodiversity Science and Management 2, 242–244.

Morgan-Davies, C., Waterhouse, A., Pollock, M.E., Holland, J., 2008. Integrating hill sheep production and newly established native woodland: achieving sustainability through multiple land use in Scotland. International Journal of Agricultural Sustainability 6, 133–147.

Müller, M., Schmitz, K., 2002. Measuring preferences for landscape functions—an application of the adaptive conjoint analysis. Agribusiness-Forshung 16, 1–15.

Müller, M., Schmitz, P.M., Thiele, H., Wronka, T., 2001. Economically and ecologically integrated valuation of land-use in less favored areas. Berichte über Landwirtschaft 79, 19–48.

National Farmers' Union, 2007. Why Beef and Sheep Farming Matters. NFU, Stoneleigh, 15 pp.

National Farmers' Union Scotland, 2007. NFU Scotland Annual Report 2007. NFUS, Ingliston, 4 pp.

National Farmers' Union Scotland, 2008. Manifesto for the hills—how to secure the future of livestock production in Scotland's Hills and Uplands. NFUS, Ingliston, 10 pp.

Nisbet, A.F., Mercer, J.A., Rantavaara, A., Hanninen, R., Vandecasteele, C., Hardeman, F., Ioannides, K.G., Tzialla, C., Ollagnon, H., Pupin, V., Jullien, T., 2005. Variation in stakeholder opinion on countermeasures across Europe. Journal of Environmental Radioactivity 83, 371–381.

PACEC, 2006. Economic and Environmental Impact of Sporting Shooting in the UK. PACEC, Cambridge, 107 pp.

Patel, M., Kok, K., Verburg, P.H., Veldkamp, T., 2007. Participatory scenario construction in land use analysis: an insight into the experiences created by stakeholder involvement in the Northern Mediterranean. Land Use Policy 24, 546–561.

Quality Meat Scotland, 2006. Quality Meat Scotland Export Strategy 2006–2007. QMS, Ingliston, 14 pp.

Quality Meat Scotland, 2007. QMS Corporate Plan. QMS, Ingliston, 10 pp.

Ramblers' Association, 2008. Ramblers' Association Aims. http://www.ramblers.org.uk/scotland/2008.

Royal National Institute for the Blind, 1999. Training in Consumer Audit/Research Techniques Focus Group Foundation. Royal National Institute for the Blind. College of Health, London, 46 pp.

Royal Society of Edinburgh, 2008. Committee of Enquiry into the Future of Scotland's Hills and Islands. Report. Royal Society of Edinburgh, Edinburgh, 170 pp.

RSPB, 2007. The Uplands—time to change? RSPB, Sandy, 14 pp.

SAC Rural Policy Centre, 2008. Farming's Retreat from the Hills. SAC, Edinburgh, 56 pp.

Sawtooth Software Inc., 2003. SMRT Advanced Simulation Module for Product Optimization. Sawtooth Software Inc., Sequim, WA. 37 pp.

Sawtooth Software Inc., 2005. Sawtooth Software SMRT [4.7]. Sawtooth Software Inc., Sequim, WA.

van Schaik, G., Dijkhuizen, A.A., Huirne, R.B.M., Benedictus, G., 1998. Adaptive conjoint analysis to determine perceived risk factors of farmers, veterinarians and AI technicians for introduction of BHV1 to dairy farms. Preventive Veterinary Medicine 37, 101–112.

Scotland's Moorland Forum, 2008. Management for delivery. Scotland's Moorland Forum, Dumfries, 6 pp.

Scottish Executive, 2003. Reform of the Common Agricultural Policy. A Summary of the Agreement. Scottish Executive, Edinburgh, 11 pp.

Scottish Executive, 2006a. Changing our ways—Scotland's Climate Change Programme. Scottish Executive, Edinburgh, 8 pp.

Scottish Executive, 2006b. A Forward Strategy for Scottish Agriculture—Next Steps. Scottish Executive, Edinburgh, 32 pp.

Scottish Government, 2008. Scottish Rural Development Programme 2007–2013, Rural Development Regulation (EC) No 1698/2005. Scottish Government, Edinburgh, 970 pp.

Scottish Natural Heritage, 2000. SNH strategy for research and technical support 2000–2005. SNH, Edinburgh, 18 pp.

Scottish Natural Heritage, 2002. Hills and Moors. Natural Heritage Futures. SNH, Battleby, 36 pp.

Scottish Natural Heritage, 2003. A natural perspective—Scottish Natural Heritage's corporate strategy—Looking forward 10 years. SNH, Perth, 23 pp.

Scottish Natural Heritage, 2008. Draft Corporate Strategy 2008-. SNH, Edinburgh, 29 pp.

Scottish Wild Land Group, 2002. Scotland's wild land—what future? Scottish Wild Land Group, Edinburgh, 34 pp.

Slee, B., Roberts, D., Barnes, A., Thomson, K., Wright, I., 2001. Agriculture's contribution to Scottish society, economy and environment: a literature review for Scottish Executive and Rural Affairs Department and CRU. Department of

Forestry, University of Aberdeen and Macaulay Land Use Research Institute, Aberdeen, 132 pp.
Soliva, R., Rønningen, K., Bella, I., Bezak, P., Cooper, T., Egil Flø, B., Marty, P., Pooter, C., 2008. Envisioning upland futures: stakeholders' responses to scenarios for Europe's mountain landscapes. Journal of Rural Studies 24,56–71.
The Mountaineering Council of Scotland, 2008. Strategic Plan 2008–2012. The Mountaineering Council of Scotland, Perth, 16 pp.
Thompson, D.B.A., MacDonald, A.J., Marsden, J.H., Galbraith, C.A., 1995. Upland heather moorland in Great Britain: a review of international importance, vegetation change and some objectives for nature conservation. Biological Conservation 71, 163–178.
Valeeva, N.I., Meuwissen, M.P., Oude Lansink, A.G.J.M., Huirne, R.B.M., 2005. Improving food safety within the dairy chain: an application of conjoint analysis. Journal of Dairy Science 88, 1601–1612.
VisitScotland, 2007. VisitScotland Corporate Plan 2007/2010. VisitScotland, Edinburgh, 54 pp.
Visser, M., Moran, J., Regan, E., Gormally, M., Skeffington, M.S., 2007. The Irish agri-environment: how turlough users and non-users view converging EU agendas of Natura 2000 and CAP. Land Use Policy 24, 362–373.
VSN International Ltd, 2005. GenStat for Windows, 8th ed. Lawes Agricultural Trust, Hemel Hempstead, UK.
Walker, S., 2001. Opportunities for balancing conflicting economic, social and environmental pressures on river basins through an integrated approach with stakeholder involvement. In: Schumann, A.H., Acreman, M.C., Davis, R., Marino, M.A., Rosbjerg, D., Jun, Xia (Eds.), Regional Management of Water Resources. IAHS Scientific Assembly, Maastricht, Netherlands, pp. 175–182.
Warren, M., 2002. Digital divides and the adoption of information and communication technologies in the UK farm sector. International Journal of Information Technology and Management 1, 385–405.
Waterhouse, A., 1996. Animal welfare and sustainability of production under extensive farming conditions—a European perspective. Applied Animal Behaviour Science 49, 29–40.
Woodland Trust Scotland, 2002. Woodland Challenges for Scotland 2002. Woodland Trust Scotland, Auchterarder, 4 pp.

Small Ruminant Research 102 (2012) 96–107

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Characterisation of farmers' responses to policy reforms in Scottish hill farming areas

Claire Morgan-Davies[a,*], Tony Waterhouse[a], Ron Wilson[b]

[a] SAC Research, West Mains Road, Edinburgh EH9 3JG, Scotland, United Kingdom
[b] University of Edinburgh, School of GeoSciences, Crew Building, West Mains Road, Edinburgh EH9 3JN, Scotland, United Kingdom

ARTICLE INFO

Article history:
Received 15 October 2010
Received in revised form 22 July 2011
Accepted 25 July 2011
Available online 13 September 2011

Keywords:
Hill farming
Multivariate analysis
CAP
Policy
Typology
Sheep
Beef

ABSTRACT

In North-western Europe, most of the land mass is classified as Less Favoured Area (LFA) under European designation and hill farms in these areas are a major contributor to the rural industry. Scotland alone is no different, as its rural land-based industry is fragile and has been dependent for many decades on high and continued levels of support payments. With recent agricultural policy reforms and changes in support for hill farmers, the future of these farming businesses is uncertain, and one purpose of this paper is to understand how they have already responded and might respond to further policy changes. This is not only important for the land use economy but also for the wider Scottish rural community and environment.

Data from three regions, typical of hill farming areas in mainland Scotland, was collated in 2007; firstly from a postal survey with 47 respondents, followed by 30 face-to-face on-farm interviews. Farmers were asked to consider three time periods (2001–2005; 2005–2007; 2008–2013) and to detail any changes they had made, or planned to make, in their management and livestock numbers. During the interviews, additional questions regarding their motivations, drive and constraints were also asked.

Fifty-three percent of the farmers surveyed had made major management changes in 2001–2005; 49% made changes in 2005–2007 and 53% projected to do so in 2008–2013. The main reported change was a decrease in animal numbers, due to economic factors, such as costs of labour and feed, and loss of subsidies. Multivariate analysis (Principal Coordinate and Cluster Analysis) of the results identified 3 clusters of farmers. Subsequent ANOVA and Chi-square analyses on the clusters showed that age, education, impact on farm labour, and impacts of neighbouring farms and their livestock reductions, were the most important factors that separated these clusters. Cluster 1 (adaptive farmers) broadly represented extensive sheep farms with farmers, who could and did diversify their income; they were also older and had the highest level of education. It was found that their animal management was greatly influenced by their neighbours' decisions. Cluster 2 (focused farmers) was reflective of relatively more intensive sheep and beef farms, with no direct interest in farm diversification. Cluster 3 (resource constrained farmers) comprised very large extensive sheep and beef farms, which were also limited by their resources. Most 'adaptive' and 'focused' farmers planned to further modify their management in 2008–2013.

Declining stock numbers in the study farms were consistent with trends in agricultural census data following the latest CAP reforms. However, the typology gave more insight of

* Corresponding author at: SAC Research, Hill & Mountain Research Centre, Crianlarich FK20 8RU, Scotland, United Kingdom. Tel.: +44 1838 400210; fax: +44 1838 400248.
E-mail addresses: claire.morgan-davies@sac.ac.uk (C. Morgan-Davies), tony.waterhouse@sac.ac.uk (A. Waterhouse), ron.wilson@ed.ac.uk (R. Wilson).

0921-4488/$ – see front matter
doi:10.1016/j.smallrumres.2011.07.013

the differing farmers' motivation and constraints when faced with reforms; this indicated that policy development should rely on multi-faceted data sources. The interdependency and fragility of these varied hill systems was highlighted by this study, pointing out the value of more targeted delivery of policy mechanisms to reflect such diversity. This is not unique to Scotland and reflects similar experiences elsewhere in Europe's marginal agricultural areas.

1. Introduction

Many pastoral systems throughout the world are in transition. In Europe, there have been widespread changes, with abandonment and farming retreat in many areas (IEEP and Veenecology, 2004). European policies, such as the Common Agriculture Policy (CAP) and its successive reforms, have been implicated in both maintaining farming systems and directly linked to changes (MacDonald et al., 2000; Royal Society of Edinburgh, 2008). As a country where agriculture is dominated by pastoral systems, which play a dual role of food production and of upholding social and rural landscapes, Scotland provides a useful case study of the factors influencing these issues.

1.1. Scotland in numbers

Scotland has an area of 7.8 million hectares and a population of 5.2 million people. Although rural Scotland only accommodates 19% of the total population, it represents 94% of the Scottish land mass (Scottish Government, 2009). Covering 72% of the country, agriculture dominates land use in Scotland. However, 86% of this is classified as Less Favoured Area (LFA) under European legislation (LFA – Article 2 of EU Council Directive No. 75/268/EEC) and suffers from natural handicaps, such as poor climate, short growing seasons, tendency of depopulation and mountainous or hilly topography (OECD, 2002). Within Scotland's agricultural area, 75% of the land is classed as rough grazing, with unimproved or semi-natural vegetation and 99% of this rough grazing is situated within the LFA.

In Scotland, 69% of the agricultural holdings are in the LFA (Scottish Government RERAD, 2010). For instance, in 2009, there were 51,993 registered agricultural holdings in Scotland, with 27% (13,983) being classified by the Scottish Government as LFA Cattle and Sheep, and only 4% (1900) classified as Lowground Cattle and Sheep. Most of the LFA Cattle and Sheep holdings are situated in the north-west and south-west of the country. Moreover, 91% of breeding ewes, and 82% of beef cows are in the LFA. Livestock farming, particularly with those classified as LFA Cattle and Sheep, is therefore the predominant land use in the hills and upland areas (Fig. 1, Scottish Government RERAD, 2010).

1.2. Scotland's marginal pastoral systems

Hill farming relies traditionally on all year round grazing, with away-wintering of the young replacement animals on lowland pastures (Symon, 1959). Most of these farms have large areas of unfenced hill grazings and smaller areas of improved fields (called inbye or intake), often fenced (Frame et al., 2003). The main output is the production of store lambs and cattle, sold for lowland fattening. Older ewes, referred to as draft ewes, are also sold for cross-breeding on farms with better land. This is the core of the stratified production system, with upland and lowland farmers buying livestock from the hills (Cooper, 2003; Dewar-Durie, 2000). These areas also traditionally acted as a genetic and breeding reservoir (Dinsdale, 1950) and are still of great importance for the lowland farming economy.

Agriculture, forestry and fisheries account for 16% of the workers in the remote rural areas (Scottish Government, 2009). The bulk of the labour force in hill farms comprises farmer-occupiers and other family members. These systems also depend upon and provide a high level of local casual employment. Local contract shepherding is in high demand for gathering, shearing or lambing, but labour availability is becoming more and more difficult (Stott et al., 2005). In addition to shepherding, livestock haulage, animal feed suppliers, and veterinary services provide a source of local or semi-local employment. These, in turn, allow for a steady local cash flow and are consequently important for the wider rural economy.

1.3. Reliance on support from policies

However, this livestock farming industry is fragile and has been dependent on high and continued levels of public support since the Second World War (Ashworth and Caraveli, 2000; Eadie, 1971; Gelan and Schwarz, 2008; Gray, 2000; Morgan-Davies et al., 2006). For instance, in 2008/2009, subsidies and support payments represented 41% of the outputs of the LFA Sheep and Cattle farms (Scottish Government RERAD, 2010). These subsidies predominantly result from the European Common Agricultural Policy (Brassley and Lobley, 2003). Before 2003, there were direct production subsidies (Sheep Annual Premium, Suckler Cow Premium and Beef Extensification Premium), based on levels of stock numbers. Also, within the LFA, payments were made on an area basis, depending upon the type or quality of hill land farmed, through the Less Favoured Area Support Scheme (LFASS), introduced in 2001 (Caskie et al., 2001).

However, in 2003, the Common Agricultural Policy Mid-Term Review set the framework of EU agricultural policy until 2013. Its key element was the decoupling of direct production subsidies, which lead to the replacement of direct support by a Single Farm Payment (SFP), irrespective of production levels or numbers of animals on the land (Oglethorpe, 2005). In Scotland, the SFP, introduced in 2005, was based on historic payments, but subject to statutory requirements and cross-compliances

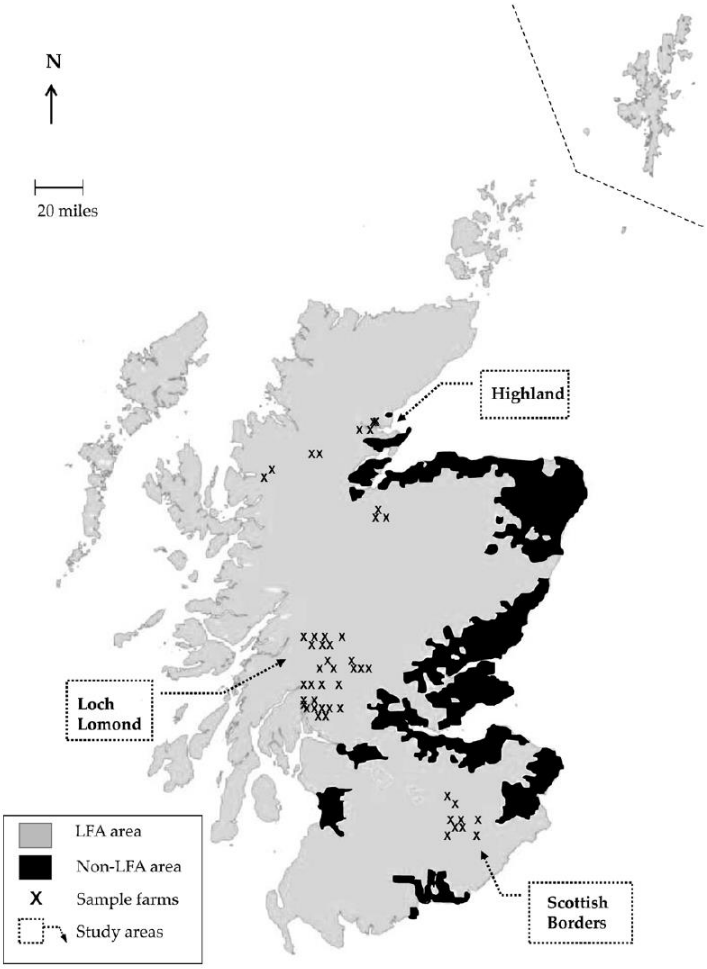


Fig. 1. LFA and non-LFA in Scotland (*Source*: Scottish Government RERAD, 2010) and location of the study sample farms.

(Scottish Executive, 2003a). In practice, farmers could reduce their livestock numbers considerably and still receive the same amount of SFP. However, concerns have been voiced about the impact of decoupling production subsidies on hill farming activity as it could herald a potential decline in animal numbers and land abandonment, as widely experienced in other parts of Europe (Strijker, 2005; Teagasc, 2003).

The impacts of agricultural policies on Scottish hill farming activities can be partly informed from agricultural census data, in particular changes in regional farm animal numbers and some farming practices. However, in-depth studies to investigate changes in farming practices and animal numbers at farm level could also be beneficial. In Spain, Milán et al. (2003) conducted surveys with 52 sheep farmers to understand the situation of their farms and the effects of agricultural policies. Similarly, Gaspar et al. (2008) studied the rationalisation of levels of management action on Spanish dehesas sheep farms following the 2003 CAP reform, using on-site interviews with 46 farmers. In these two studies, the authors used typologies or categorisation techniques. Although each farm has its unique set of resources and problems, it is valuable to be able to classify them into simpler groupings to enable policy solutions to be considered somewhere between individual farm and whole industry levels.

For this study, census data for the Scottish hill and upland areas were compared with results from a survey and detailed interviews with farmers, to obtain information on whether or not the most recent CAP reform and the decoupling of production subsidies caused changes in animal numbers and management in the hills of Scotland. In order to encapsulate the 2003 CAP Mid-Term Review, three time-periods were considered: 2001–2005, period when the review was announced, 2005–2007, when the Single Farm Payment was introduced in Scotland, and 2008–2013 (the future).

The aims of this paper therefore were (a) to explore changes in breeding ewes and beef cows numbers in the hill farming areas of Scotland using census data over three periods, (b) to find out what changes had occurred at farm level in some of these areas, over the three same periods and compare it with the census, and (c) to identify if some characteristics of farm types, as well as motivation of farmers can explain these changes.

2. Methods

2.1. Agricultural census data

In Scotland, agricultural census data are reported by region (North West, North East, South West and South East), and, within each region, by groupings of local authorities areas. Data are also published by LFA and non-LFA areas.

For the purpose of this study, census data relating to numbers of breeding ewes and beef cows were compiled at regional level and at LFA/non-LFA level, for the period between 2001 and 2007.

Data were also compiled at the local authority level, for those authorities where hill farming is the dominant land use, with low stocking density of livestock and a high proportion of rough grazing. These were the Highland (North West region), the Scottish Borders (South East region) and Argyll and Bute (South West region).

2.2. Survey and interviews data

2.2.1. Study areas

For this analysis, data was drawn together from linked farm-scale studies in these three aforementioned local authority groups:

- Highland, in the North West region of Scotland:

  The total Highland area is 2.15 million hectares (35% of the whole of Scotland and 80% of the North West region). It has extensive areas of high ground and includes the highest point in the UK (Ben Nevis, 1344 m). The mean annual temperature is about 8.5 °C but on highest ground, the annual mean is just below 0 °C. The coldest month is January or February and the warmest is July or August, but the daily maxima are less than 16 °C. The frost free season is often as short as 3 months. Much of this area is exposed to rain-bearing westerly winds and as a result the average annual rainfall is at least 1700 mm, with the wettest area being to the northwest of Ben Nevis (over 4000 mm per year) (Met Office, 2011).

  The main agricultural land use is livestock grazing (72% of the area is rough grazing, which is unimproved or semi-natural vegetation, 14% is common rough grazing and 5% permanent pasture (grass older than 5 years)). Five percent of the agricultural area is woodland and only 4% is arable. Although the main livestock productions are sheep and beef, there are very small numbers of farmed deer, pigs and goats (Scottish Government, 2008).
- Around Loch Lomond, in Argyll and Bute in the South West region:

  Argyll and Bute has a total area of 0.49 million hectares (8% of the whole of Scotland and 31% of the South West region). Much of the landscape consists of high ground; however, the climate is milder than that of Northern or Eastern Scotland due to the stronger maritime influence, as the prevailing winds blow from the sea. As the result, the annual mean temperatures are around 9.3 °C. July or August are the warmest months, but mean daily maxima only reach 14.6 °C on the highest ground. The average annual rainfall is over 3500 mm, with a marked seasonal variation (autumn and early winter are the wettest seasons). The area is also one of the more exposed areas of the UK, being close to the Atlantic, with several noteworthy major storms recently affecting it (Met Office, 2011).

  With 80% of the area being rough grazing, and 8% permanent pasture, the main land use is livestock grazing. Six percent of the agricultural area is woodland and 3% is arable. The main livestock productions are sheep and cattle (including some dairy cows), but also small numbers of farmed deer and goats (Scottish Government, 2008).
- The Scottish Borders, in the South East region:

  The total area of the Scottish Borders is 0.38 million hectares (6% of the whole of Scotland and 20% of the South East region). The mean annual temperature is less than 6 °C on higher ground, with the coldest month being January or February, where temperatures can be less than −2 °C. However, July is the warmest month and temperature can reach 20 °C at low levels, the highest in Scotland. Most of Eastern Scotland is sheltered from the rain-bearing westerly winds, so the average annual rainfall varies between 700 mm and over 1500 mm (Met Office, 2011).

  Although the land use is predominantly livestock grazing (42% is rough grazing and 24% is permanent pasture), there is more arable land (28%) with some tillage crops. Five percent of the agricultural area is woodland. The major livestock production is sheep. There are also some beef and pigs, and a substantial number of poultry (18% of the total number of birds in Scotland) (Scottish Government, 2008).

2.2.2. Data collection

The data collection for the research was carried out in two steps:

1. A postal survey with hill farmers.
2. A series of face to face interviews with hill farmers.

1. Postal survey

   The aims of this survey were principally to identify some of the main changes that hill farmers had made or were making in these areas since the introduction of the 2003 CAP reform.

   Using local lists from SAC researchers and agricultural consultants, 50 hill farmers from Loch Lomond and the Highland were contacted in the winter of 2006–2007. In total, 23 farmers responded (Table 1).

   They were asked specific questions about:
   - Their farm characteristics, animal numbers, labour and production type
   - Any changes in animal numbers and management and the reasons behind these changes. Changes within three particular periods were considered, centred on the most recent reform of the CAP:
     a) 2001–2005 (announcement of the CAP review).
     b) 2005–2007 (introduction of Single Farm Payment – SFP).
     c) 2008–2013 (review of SFP).

   The design of the questionnaire adhered to the principles of Fowler (2002) and comprised both open and closed questions.
2. Face to face interviews

   In addition to the postal survey, face-to-face interviews with farmers were carried out from May to November 2007, in the Loch Lomond and the Scottish Borders areas.

   The aim of these farm interviews was to understand in more detail the changes farmers had made in 2001–2005 and 2005–2007, and to gauge the potential impacts of these changes on their farm and the immediate wider rural economy, as well as their future plans.

   Farmers' addresses were found using both local lists from SAC researchers and agricultural consultants, and local business directories on the Internet (www.yell.co.uk/farmers). Stratified sampling by postcode was then used. In total, 65 farmers were contacted, first with an advance letter (as advised by Dillman, 1978), then followed by a phone call to arrange a visit. Due to willingness, timing and busy farm schedules, only thirty interviews were subsequently conducted in Loch Lomond and the Scottish Borders (Table 1). Six of the hill farmers from Loch Lomond had previously responded to the postal questionnaire.

   All interviews were conducted by the same person and lasted approximately 2 h. Interviewees were asked detailed information on:
   - Animal numbers and locations.
   - Farm characteristics, changes in animal numbers and management (including many of the same core questions that were part of the postal questionnaire).
   - Farm management and farm infrastructure.

Table 1
Research steps, variables obtained and number of datasets.

Variables obtained	Research steps		
	1. Postal survey	2. Interviews	Total
Farm characteristics and changes in animal numbers and management	23 datasets	24 datasets[a]	47 datasets "sample farms"
Detailed farm husbandry, farmers motivations, views and impacts of changes	None	30 datasets	30 datasets "interview farms"

[a] Six farms out of the 30 interview farms had responded previously to the postal survey.

- Their views on risk, opportunities, and the future of farming.

They were asked to consider the same three time-periods as in the postal questionnaire. Table 1 summarises the approach, the variables and the datasets obtained in these two steps.

2.3. Analysis

Descriptive statistics using a statistical package (Genstat 8th edition, VSN International Ltd, 2005) were used to analyse the results of the survey. Multivariate analysis was subsequently used on the interview results, to identify groups of farmers and farms.

In the literature, groupings and typologies are usually based on Principal Component Analysis (PCA) or Principal Coordinate Analysis (PCO), followed by Hierarchical Clustering (Riedel et al., 2007; Gorton et al., 2008).

PCA is a technique for reducing the dimensionality of a data set of continuous variables. It takes a set of (p) variables and replaces them by a small number (r) of new variables, called the principal components (or dimensions), in such a way that nearly all the information in the original variables is retained in the new ones. The coordinates of the samples on this new dimension are called the scores. When variables are non-continuous, PCO analysis is used to obtain the scores (Brocklehurst, *pers. comm.*). Once the dimensions have been interpreted, Cluster Analysis can be carried out on the scores of the dimensions which explained most of the variation, to group the samples on these particular variables (McNicol and Hirst, 2004).

In this study, variables were both discrete and continuous, so analysis was carried out by means of a customised statistical program from Biomathematics and Statistics Scotland (BioSS), using Genstat 8th edition (VSN International Ltd, 2005). The program created a similarity matrix between the interview farms data, using a simple matching method; this similarity matrix was then used in a subsequent PCO analysis. A non-Hierarchical Cluster Analysis, using Euclidean distance, was then carried out on the PCO scores.

A total of 149 variables were used in the analysis. Variables relating to some socio-economic aspects and to the CAP reform were not included in the initial analysis and were used afterwards to further analyse each of the clusters, as proposed by Gorton et al. (2008). ANOVA was used on the continuous variables and Kruskall–Wallis (Chi-square) was used on the discrete variables, in order to check the statistical differences between the obtained clusters.

3. Results

3.1. Agricultural census

In Scotland, between 2001 and 2007, there has been a reduction of 11% in the number of breeding ewes (from 3.28 millions to 2.92 millions). The number of beef cows decreased by 3% over the same period (from 489,000 to 472,000). However, there were regional differences. In the North West, the reduction in the number of breeding ewes reached 24%, in the North East, 8%, in the South West, 6% and in the South East, only 5%. For the beef cows, the reductions were less dramatic. The North West lost 8% of its number of beef cows, the North East, 3%, the South West 7% but the South East saw an increase of 1%. The North West was the region the most affected by the loss of ewes and beef cows. In the LFA areas, the number of breeding ewes decreased by 12% over that period, whilst the number of beef cows decreased by 4%. The non-LFA areas saw a decrease of only 1% in the number of breeding ewes, whilst beef cow numbers increased by 1% (Scottish Executive, 2002a, 2004a, 2006a; Scottish Government RERAD, 2008).

In the Highland, the reduction in breeding ewe numbers between 2001 and 2007 was 24%; Argyll and Bute saw similar reductions (20%). The Scottish Borders, however, saw an increase of 2% in its number of breeding ewes over the same period. There were significant numbers of reduction in sheep within some of this area due to major slaughtering in the Foot and Mouth outbreak of 2001. Beef cow numbers also decreased in the Highland (by 10%) and in Argyll and Bute (by 12%). The reduction in beef cow numbers in the Scottish Borders was, however, less pronounced (only 2%) (Scottish Executive, 2002b, 2004b, 2006b; Scottish Government, 2008).

3.2. Descriptive analysis of the survey and the interviews

Data relating to the characteristics of the farms, collected during the survey and the interviews, illustrates the diversity of hill farms in the sample (Table 2). On average, farms had less than 2000 ha of land; however, farms in the Highland region had larger average areas (>3000 ha). There were large disparities in the flock sizes and herd sizes, as reflected in the large standard deviations.

Fifty-three percent of the farmers carried out changes in 2001–2005, when the majority decreased sheep numbers (Table 3). In 2005–2007, 49% of the farmers reported changes; of those, 74% decreased their sheep and cows numbers. When asked about the future (2008–2013), 53% planned to change their management. A quarter of them said they would decrease their sheep numbers. However, 38% had other ideas, such as diversification (housing, tourist accommodation), growing cereals, forestry or retirement. The main reasons given by farmers for these changes were due to economic factors (costs and availability of labour, costs of feed and lack of value in the outputs, loss of subsidies). However, the need to abide to Scottish agri-environmental schemes (Countryside Premium Scheme, Rural Stewardship Scheme) or LFASS rules were also mentioned. Retirement, increasing age and reducing the work of handling livestock were also part of the rationale for change.

The reduction of ewe numbers in the sample averaged 15% (from 1150 ewes down to 980 between 2001 and 2007). However, the Loch Lomond area showed the

Table 2
Results from the descriptive analysis (47 datasets) for the three areas.

Variables	Unit	Highland		Loch Lomond		Scottish Borders		Total	
		Mean value	Frequency	Mean value	Frequency	Mean value	Frequency	Mean value	Frequency
Tenanted farms	Farm	6	0.60	11	0.39	5	0.56	22	0.47
Owner-occupier farms	Farm	2	0.20	14	0.50	2	0.22	18	0.38
Mixed tenancy	Farm	2	0.20	3	0.11	2	0.22	7	0.15
Sheep only farms	Farm	2	0.20	12	0.43	5	0.56	19	0.40
Cattle only farms	Farm	0	0.00	2	0.07	0	0.00	2	0.04
Sheep & cattle farms	Farm	8	0.80	13	0.46	4	0.44	25	0.53
Other farms	Farm	0	0.00	1	0.04	0	0.00	1	0.02
Farmers' age									
18–30 years old	Farmer	0	0.00	1	0.04	0	0.00	1	0.02
31–45 years old	Farmer	2	0.20	9	0.32	2	0.22	13	0.28
46–60 years old	Farmer	3	0.30	10	0.36	6	0.67	19	0.40
>60 years old	Farmer	5	0.50	8	0.29	1	0.11	14	0.30
		Mean value	StDev	Mean value	StDev	Mean value	StDev	Mean value	StDev
Farm size	Ha	3348	2876	1279	1064	965	553	1680	1793
Inbye size	Ha	234	353	51	64	73	47	94	186
Hill size	Ha	3101	2708	991	1094	892	557	1421	1724
Flock size	Ewe	778	411	919	832	1060	417	916	692
Herd size	Cow	66	85	27	30	57	56	41	53

greatest reduction, with an average loss of 18% of the animals (from 1220 ewes down to 1000, on average).

3.3. *Typology on the interviews*

The PCO used 149 variables (107 discrete and 42 continuous). These covered farm characteristics, farmers' motivations and views of risks. Five dimensions were retained in the analysis, since there was a significant decline in the percentage variation between the 5th and 6th dimensions. The five dimensions explained 64% of the total variation. The variables which were correlated ($r \geq |0.5|$) with any of the 5 dimensions were investigated for interpretation purposes (Table 4). When two or more variables were strongly correlated ($r > |0.8|$), only one was kept, as suggested by Köbrich et al. (2003). With the subsequent non-Hierarchical Cluster Analysis on the PCO scores, it was possible to identify 3 homogeneous clusters of farms (Fig. 2). The first cluster comprised 7 farms, the second, 10 farms and the third cluster, 13 farms. Looking at the 1st and 2nd dimensions of the PCO, the clusters of farms were clearly distinct, but less so when other pairs of dimensions were used (Fig. 2). However, the analysis of variances conducted (ANOVA and Kruskall–Wallis Chi-square) showed that these three clusters were statistically distinct on many variables (Table 4).

The first cluster, which represented 23% of the farms, comprised extensive sheep farms, with a medium number of ewes (on average, 930), but with a low productivity (94% lambing percentage – number of lambs weaned per 100 ewes). Grazed forage was the limiting factor for their ewe numbers and most of them fed the ewes in winter. Only half of them had their ewes ultrasound scanned at mid-pregnancy. Most of the animals produced were sold as store. Contractors were mainly employed at gathering times. Most farmers were tenants. All of the farmers agreed on diversifying their income and half of them already had forestry on their farm. Most of them would use their

Table 3
Change options, as reported by the farmers, for 2001–2005, 2005–2007 and 2008–2013 (some farms carried out more than one option, hence the percentages do not add up to 100%).

Options	Period					
	2001–2005 (Actual actions)		2005–2007 (Actual actions)		2008–2013 (Projected actions)	
	No. of farms	%	No. of farms	%	No. of farms	%
No change	22	47%	24	51%	22	47%
Changes	25	53%	23	49%	25	53%
	No. of farms	% of those who changed	No. of farms	% of those who changed	No. of farms	% of those who changed
Decrease sheep	15	48%	15	48%	7	24%
Decrease cows	3	6%	8	3%	3	3%
Increase sheep	2	10%	1	26%	1	10%
Increase cows	5	16%	1	3%	3	10%
Change management	6	19%	1	3%	4	14%
Others	0	0	5[a]	16%	11[b]	38%

[a] Includes forestry options, land improvement and succession.
[b] Includes housing, tourism accommodation, forestry options, hydro-electric scheme, succession, changing tenancy, growing cereals.

Table 4
Characteristics of the clusters obtained in the analysis by PCO dimensions (majority of answers shown in brackets).

			Clusters			
			1 'adaptive'	2 'focused'	3 'resource constrained'	
Number of farms in cluster			7	10	13	
PCO dimension	***r***	**Name of variable**	**Clusters: 1 'adaptive'**	**2 'focused'**	**3 'resource constrained'**	**Sig.**
1 (18% of variation)	−0.8	Do you calve in Autumn?	n/a	No (5)/yes (3)	No (11)	<0.001
	−0.8	Do you calve in Summer?	n/a	No (5)/yes (3)	No	<0.001
	−0.7	Do you calve in Spring?	n/a	No (6)	Yes (12)	<0.001
	0.6	Is the max number of ewes your farm could carry constrained by forage?	Yes (5)	No	No (12)	<0.001
	−0.6	% lambs sold finished	1%	94%	35%	<0.001
	−0.6	Number of cattle	0	59	40	<0.01
	0.6	Ranking of farming activity	2nd (4)/1st (3)	1st (9)	1st (10)	NS
2 (14% of variation)	0.6	Ewe productivity (lamb weaned/100 ewes)	94%	124%	80%	0.001
	−0.6	Do you feed the ewes in winter?	Yes (6)	Yes (10)	No (9)	<0.001
	−0.6	Type of farm[a]	LFAs	LFAb + s (5)/LFAs (5)	LFAb + s (11)/LFAb (2)	<0.001
	0.6	Do you scan your ewes?	Yes (4)/no (3)	Yes (9)	Yes (6)/no (5)	NS
	0.6	% calves sold store	n/a	57%	92%	<0.001
	0.5	No silage is produced on the farm	Yes (4)/no (3)	No	No (9)	<0.05
	−0.5	There will be a steady decline until the economic situation improves[b]	Ag (5)/Ne (2)	Ag (7), Sag (2)	Ag (12)	NS
	0.5	Are distances an issue on your farm?	No	No	No/yes	<0.01
	−0.5	Local residents are not sympathetic to farmers and their needs[b]	Ag (4)/Dis (2)	Dis (8)	Ag (8)/Dis (5)	<0.05
	0.5	No hay is produced on the farm	Yes	No (7)	Yes (9)	<0.05
	−0.5	My buildings are fit for purpose	Yes	Yes (9)	No (7)/yes (6)	<0.05
3 (11% of variation)	0.7	Ewe numbers (main flock)	931	776	1432	NS
	0.7	Max number of ewes the farm could carry	1160	1012	1458	NS
	0.7	Do contractors do the gathering?	Yes (5)	No (9)	Yes (9)	<0.01
	0.6	Number of people needed for the biggest gather	3	1.6	4.5	<0.05
	−0.5	I will try to diversify my income[b]	Sag (2), Ag (5)	Ag (5)/Dis (2)/Ne (3)	Ag (9), Sag (1)	NS
	−0.5	Is the maximum of ewes your farm could carry constrained by labour?	No (6)	No (7)	No (8)/yes (5)	NS
4 (11% of variation)	0.5	% time the spouse works off-farm in non-farming activities	14%	85%	44%	NS
	0.5	Would you be prepared to borrow money to start a new venture?	Yes (4)/no (3)	Yes (6)/no (4)	Yes (10)	NS
	0.5	There is no future in hill farming[b]	Ag (2)/Dis (4)	Dis (6), Sdis (1)/Ag (3)	Ag (5)/Ne (4)/Dis (4)	NS
	0.5	Are you an owner-occupier?	No (5)	No (7)	Yes (10)	<0.05
	0.5	I want to farm with less subsidies[b]	Sag (2), Ag (2)/Ne (2)	Ag (8), Sag (1)	Ag (7), Sag (2)/Dis (3)	NS
	−0.5	As a farmer, I am a respected member of the local community[b]	Ag (5)/Ne (2)	Ag (9)	Ag (8)/Dis (3)	NS
5 (10% of variation)	0.6	Would you use your resources for things other than farming?	Yes (5)	Yes (7)	No (7)/yes (6)	NS
	−0.5	My buildings are fit if my stock numbers were to increase	Yes (4)/no (3)	No (7)	No (7)/yes (6)	NS
	0.5	Would you be prepared to do things other than farming?	Yes (6)	Yes (7)	Yes (11)	NS
	0.5	What is your motivation?[c]	2 (2); 3 (2); 4 (2)	2 (4); 4 (4)	1 (3); 2 (5); 4 (3)	NS
	0.5	Do you have forestry activities on your farm?	No (4)/yes (3)	No	No (11)	NS

[a] LFAs = LFA sheep farms; LFAs + b = LFA sheep and beef farms; LFAb = LFA beef farms.
[b] Likert scale: Sag = strongly agree; Ag = agree; Ne = neutral; Dis = disagree; Sdis = strongly disagree.
[c] 1 = profitability until I retire; 2 = providing a working system for the next generation; 3 = developing an environmentally friendly system, even though not always profitable; 4 = enjoy farming and will carry on regardless.

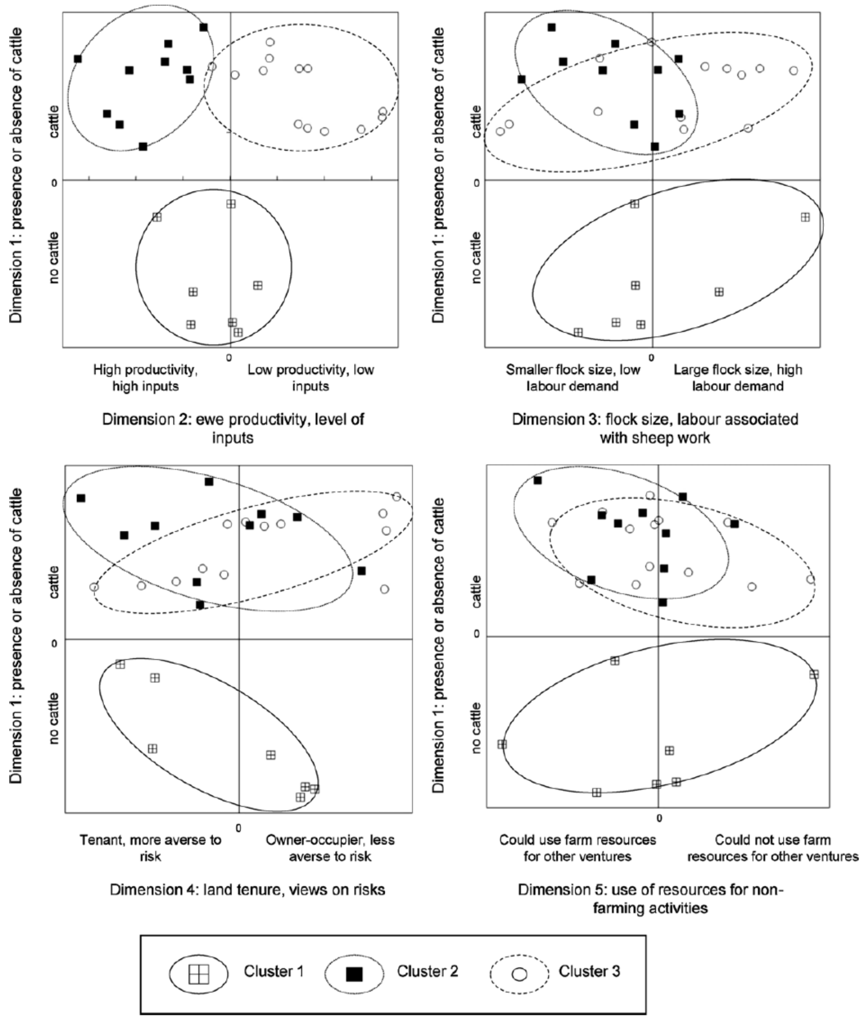


Fig. 2. Positioning of the 30 interview farms according to the five principal dimensions and by the three identified clusters.

resources differently and be prepared to start ventures other than farming; in this respect, they could be labelled as adaptive farmers ('adaptive').

The second cluster contained 33% of the interview farms and was reflective of the more intensive sheep and beef farms. These farms had the lowest number of ewes (on average, 780) but their productivity was the best (124%). They also had the highest number of cows (59 on average). All the farmers fed their ewes in winter and produced their own silage and hay. Most of the young animals were sold finished. Contractors were not used for sheep work. Most farmers were tenants and their spouses had a job outside farming. They strongly believed that there was a future in hill farming and had strong positive views on farming without subsidies. They stated that farming came first in terms of their income and had mixed views on diversification. In summary, they could be labelled as farmers focused on farming ('focused').

The last cluster, which was the largest with 44% of the farms, represented very large extensive sheep and beef

Table 5
Further analyses of the clusters according to the socio-economic variables and to the CAP reform outcomes, external to the primary analysis (significant differences in bold).

Name of variable	Clusters 1 'adaptive'	2 'focused'	3 'resource constrained'	Sig.
Level of education	Univ/Higher qual.	Secondary	Secondary	**$P<0.05$**
Age bracket	Over 60 years	46–60 years	31–45 years	**$P<0.05$**
Years in the area	28	43	35	NS
Do you have a long-term plan?	No	Yes	No/yes	NS
Do you have a successor?	Yes	No/yes	No/yes	NS
Have you made any change in 2001–2005?	No	Yes/no	Yes	NS
Have you reduced your livestock in 2001–2005?	Yes	Yes/no	Yes	NS
Influences of 2001–2005 changes on paid labour	Decrease	Mix	Same	**$P<0.05$**
Influences of 2001–2005 changes on unpaid labour	Same	Mix	Mix	NS
Influences of 2001–2005 changes on habitat	Same/increase	Don't know	Same/increase	NS
Influences of 2001–2005 changes on the local economy	Same/increase	Don't know/same	Same	NS
Have you made any change in 2005–2007?	Yes/no	No	Yes/no	NS
Have you reduced your livestock in 2005–2007?	Yes/no	Yes	Yes	NS
Influences of 2005–2007 changes on paid labour	Same	Don't know	Same	NS
Influences of 2005–2007 changes on unpaid labour	Same	Don't know	Decrease/same	NS
Influences of 2005–2007 changes on habitat	Increase	Don't know	Mix	NS
Influences of 2005–2007 changes on the local economy	Same	Don't know	Same	NS
Were these 2005–2007 changes a result of the CAP reform?	No	No	Yes/no	NS
Post-CAP reform, your farming will be:	Mix	Same/easy	Same/easy	NS
Have your neighbours made any changes in 2005–2007?	Yes	Yes/no	Yes	NS
Will these 2005–2007 changes affect your management?	Yes	No	No/yes	**$P<0.05$**

farms, constrained by their resources. They had the highest number of ewes (1430 on average) but the lowest ewe productivity (80%). They had a medium number of cows (40 on average), which were spring calving. Two-third of the lambs and nearly all calves were sold as store. Silage was produced on the farms but not hay. The farmers did not feed the ewes in the winter, and only half of them had their ewes ultrasound scanned at mid-pregnancy. They stressed that their ewe numbers were limited by the labour availability on the farm, and sheep gatherings required the highest number of people (4.5 people on average). Most farms were owner-occupied. These farmers strongly agreed on value of diversification but, in terms of infrastructures, half of them thought their buildings were not fit for purpose and could not be used for any other venture. In summary, this group could be labelled as resource constrained farmers ('resource constrained').

To further analyse the clusters, a set of variables, excluded from the primary analysis and related to demographic, future intentions and responses to the CAP reform, was used. Statistical differences (ANOVA and Chi-square) between the clusters concerned the age of the farmers and their level of education, with the 'adaptive' farmers being the most educated and the oldest, whilst the 'resource constrained' farmers were the youngest (Table 5). The influences of the 2001–2005 changes on paid labour force and whether or not the changes their neighbours had made (in 2005–2007) would affect their own management decisions were also statistically different between the three clusters (Table 5). Indeed, the 'adaptive' farmers thought that their paid labour would decrease and that changes made by their neighbours would affect them. Conversely, the 'focused' farmers did not think they would be affected by their neighbours' decisions.

4. Discussion

Results from the agricultural census data showed that since 2001, breeding ewe and beef cows numbers have declined in Scotland. This decline is more dramatic in the more extensive hill farming areas, where livestock density is low and where rough grazing is predominant. The census data also showed that this decline is particularly more pronounced since 2005, when the Single Farm Payment was introduced. The data obtained during the survey and interviews concur with such a decline. Indeed, on average, a reduction of 15% in the number of breeding ewes was observed in the survey and interview farms; this being similar to the average loss of 13% recorded in the census over the same period. However, it was in the Argyll and Bute survey and interview farms that the biggest reduction was observed (18%), whilst in the census, the Highland region showed the largest reduction (24%).

The typology approach used in this study sheds some light on the reasons and impacts behind such declines and is complementary to the census data analysis. Indeed, although farm typologies, in Scotland or elsewhere, have been widely used (mostly by government for reporting farm statistics), they are mainly based on the type of production or land quality. These typologies do not take into account the farmers' views, attitudes and goals, which often play a very important role in the day to day management of their business (Brodt et al., 2006; Fairweather and Keating, 1994). Girard et al. (2008), in the French Pyrenees, equally stressed the importance of "characterising the diversity of farming practices and analysing the reasons why farmers do what they do".

This study also relied on what could be considered relatively small sample sizes, both for the survey and for the interviews. However, although some studies report larger sample sizes (e.g. Milán et al. (2006) used data from 130 cattle farms; Willock et al. (1999) reported on 245 Scottish farms), more detailed farm level studies have tended to use small samples. Indeed, Olaizola et al. (2008) in Spain studied new feeding technology in sheep farming systems and used two samples of 23 and 79 sheep farms respectively. Girard et al. (2008) interviewed 33 hill farmers to categorise farming practices in mountain areas in France and Acs et al. (2010) surveyed 44 hill farms in the Peak District to investigate land management. Moreover, our survey and interviews were conducted consecutively and both sets of results were analysed simultaneously. Although we contacted a large and varied sample of farmers in each area (e.g. from small farms to larger estates), ultimately there was a bias towards self-selection, which may have limited the range of data compiled. However, the sample was considered typical of the farming areas chosen, whilst perhaps not being fully representative.

The three clusters identified in this study showed not only the disparities in farm characteristics, but also the disparities in farmers' views. This reinforced the fact that hill farms in Scotland vary in size, number of animals and type of outputs. It is our view that this diversity needs to be acknowledged in policy making. For instance, farm labour, which is an important factor in extensive conditions in the UK and in Europe (Caballero, 2001; Stott et al., 2005), was different across the clusters. It was a significantly more important issue for the 'adaptive' farmers. These extensive sheep farmers were dependent on contractors and reducing livestock numbers was a way of reducing labour costs (as shown by Stott et al., 2010); this reinforced the crucial role that skilled farm labour has in the hill farming industry.

The typology also identified constraints that hill farmers are facing, something that census data alone could not provide. This may dictate how, in the future, hill farmers could react to the coming changes in subsidy regime, especially with respect to agri-environment or diversification measures such as those found in the Scottish Rural Development Programme (Rural Development Regulation (EC) No. 1698-2005). Indeed, the 'adaptive' cluster, despite being made of farmers ready to diversify, was composed of older farmers. The question of farm succession or continuity becomes a potential threat, as already reported by Caballero (2001) and Riedel et al. (2007). These farmers were also those with the highest education level, and who, according to Gorton et al. (2008), may have been more able to diversify off-farm. Gasson (1998) also reported education level as being a key factor which "induces farmers to participate in schemes". Conversely, farmers in the 'resource constrained' cluster had a limited capacity for adaptation. This echoes what Franks (2006) and Gelan and Schwarz (2008) argued in their research, that not all hill farmers can diversify their business, due to the low opportunity costs of farmers' own labour. Farm tenure conditions and relationships between landlords were also major restricting factors. So, even if diversification seems to be an option for some farmers, as recent research in the English uplands has shown (Defra Agricultural Change and Environment Observatory, 2009), our results suggest that it is not always a feasible one.

The importance of the behaviour of neighbouring farmers was a major factor highlighted in the typology analysis (Table 5) and would not have been picked up by census data analysis. Here it was shown that the extensive farms were more affected by changes carried out by their neighbours. Indeed, in these types of environment, grazing hills are large and unfenced, and any changes in stocking density in one part of a hill will greatly affect livestock management. Farmers, who reported being affected by their neighbours, had to destock or re-arrange their flock's spatial distribution to avoid their animals straying or to improve sheep gathering conditions. This demonstrates how linked hill farms can be and how decisions by one individual farmer can affect the whole 'local' fabric. This interdependency has been further observed by Gray (2000) in the Scottish Borders, who states that there is "a causal link between family farming and the preservation of rural society". Caballero (2001) also stresses the fact that "the assumption that the choices made by one producer are more or less unaffected by the choices of another [. . .] cannot be taken for granted". High levels of hill farming interdependency bring with them the unwelcome prospect that as neighbouring businesses disappear, those remaining become less tenable.

At a wider level, this study's results are also an example of what can happen in farming areas dependent upon extensive pastoral systems. Agricultural and rural activities decline and abandonment is a risk. This has already been highlighted in other parts of Europe, especially the states of Eastern Europe which have witnessed dramatic agricultural changes (Moravec and Zemeckis, 2007), and for Southern European mountainous areas, where adjustments have been occurring over a long period. However, for the UK, such recent changes in animal numbers following a long period of stability during the production subsidy eras of the 1980s and 1990s, demonstrate how policy can have a large impact on marginal pastoral areas. This also highlights the continued dependency of hill farming and pastoral systems on financial support, as reported by Strijker (2005) and also by Pack (2010), in the latest review into the Less Favoured Area Support Scheme for Scotland. Caballero et al. (2007) encapsulated the problem when stating that these systems are "dependent on public handouts for survival, but successive policy schemes have only showed mixed effects and, [. . .], clear inconsistencies in their aim to stop the general declining trend of LSGS [large scale grazing systems]", and advocating "better-focused policy intervention". This issue is therefore not confined solely to Scotland but relates to many marginal and extensive hill areas in Europe.

That the latest CAP reform policies have not been altogether a success for Scotland's marginal pastoral systems is evident in this study. Whilst it was recognised in the setting of the CAP reform that "regional shifts in the pattern of livestock production may bring change to the most peripheral areas" (Scottish Executive, 2003b), the dramatic impacts on sheep numbers in the hills were not entirely anticipated. This reiterates the difficulty of formulating a single policy for marginal agriculture areas, where the role of farming is multi-faceted: producing food, helping to maintain the prosperity of rural communities and protecting and enhancing the environment. In this context, it is therefore important to discuss how further policy should be altered to accommodate the extra layer of information that the typology brought. Which policy instruments would be most appropriate for each of the clusters here identified?

The 'adaptive' farmers are innovators and as such represent the imaginative and entrepreneurial spirit that needs to be fostered. They are more likely to respond to policy mechanisms that encourage business improvements and diversification, possible through the Scottish Rural Development Programme options (Scottish Government, 2010). Dependence upon the SFP could be reduced more easily with this group. Conversely, the 'focused' farmers are dedicated to food production and are therefore important from a food security viewpoint. They are more likely to welcome policy mechanisms that foster the production aspects of their business. With EU agricultural policy currently committed to decoupling support from production, then the SFP would still be the most appropriate primary support mechanism, but making a larger share of the total budget available for upgrading production resources (such as buildings and equipment) or for co-operative activities associated with production, could be routes favoured by this group. Finally, the 'resource constrained' farmers represent the biggest and most vulnerable group and as such, is the one which would naturally continue the current trend of reductions in size of business and of risk of farm abandonment, under normal market forces. However, if these farms are to be retained for their multi-faceted roles such as maintaining rural communities (preventing the tipping point or domino effect referred to earlier), contributing to food production and providing environmental goods and services, then the SFP is probably still the best vehicle for support, as these farmers inherently lack the capacity to adapt and change. The opportunities offered through the Scottish Rural Development Programme are probably of less relevance to these farmers as they may lack the wherewithal or impetus to access them. For them personally some opportunity to leave farming might be the most appropriate, but whether this is in the national interest is another issue. In more intensive areas, the land would be taken up by neighbouring farmers or by new entrants, but in extensive areas, as mentioned earlier, the land may cease to be farmed.

There are some final implications to this simple split of policy support proposals. Firstly, representativeness is key, as it would be necessary to ensure that all hill farmers in Scotland belong to these 3 clusters. Although the sample farms in this study were typical of their areas, perhaps more clusters would be identified if more areas were considered. This aspect could be tested by choosing other hill areas at random and test whether or not they could by classified by this typology. Secondly, it is necessary to establish to which typology a particular farm or group of farms belongs. If membership of a cluster cannot be easily identified through a few additional questions in the annual census, then this becomes a difficult exercise. Finally, the stability of these clusters needs to be established, i.e., would farmers remain in their clusters or move due to changes in circumstances? Most of these are not in the scope of this study, but need to be addressed in the future if more innovative approaches for delivery of policy instruments that recognise hill farm diversity are to be valid.

5. Conclusions

In conclusion, this research reinforces the view that since the latest policy reforms, animal numbers in marginal areas have decreased dramatically. It also showed that hill farmers and their farms are diverse and that this diversity needs to be recognised when formulating policies. Using a typology approach to do so could be a useful adjunct.

Moreover, the interdependency of these hill farming systems is also of considerable importance, when action by one individual farm has repercussions across the wider local area. This complexity of situations, constraints and motivations helps to explain the difficulty of formulating effective policy appropriate for these extensive and marginal systems.

Finally, this study points out the value of multi-faceted data sources to help inform policy formulation, and more targeted delivery of policy mechanisms to reflect the diversity within extensive farming systems. Although agricultural census data can offer cost-effective nation-wide metrics such as crop area and animal number trends, small scale interviews do provide different layers of detail useful to policy makers. Farm typologies can be helpful in predicting impacts of future policy changes at local area or farm level. Knowing the constraints at farm level and the deeper motivation of the farmers should allow better predictions of farmers' response to policy changes.

Acknowledgments

SAC receives financial support from Scottish Government. Loch Lomond and the Trossachs National Park supported data collection from the farmers in this location. Sarah Brocklehurst from BioSS is gratefully acknowledged for her invaluable help in building the statistical model to analyse the farm interviews data. The authors also wish to thank the farmers who took part in the survey and the interviews, as well as the two anonymous reviewers for their valuable comments on the manuscript.

References

Acs, S., Hanley, N., Dallimer, M., Gaston, K.J., Robertson, P., Wilson, P., Armsworth, P.R., 2010. The effect of decoupling on marginal agricultural systems: Implications for farm incomes, land use and upland ecology. Land Use Policy 27, 55–563.

Ashworth, S., Caraveli, H., 2000. The sheepmeat and goatmeat regime. In: Brouwer, F., Lowe, P. (Eds.), CAP Regimes and the European Countryside: Prospects for Integration Between Agricultural, Regional and Environmental Policies. CABI Publishing, Wallingford, pp. 71–86.

Brassley, P.W., Lobley, M., 2003. The Common Agricultural Policy of the European Union. In: Soffe, R.J. (Ed.), Primrose McConnell's The Agricultural Notebook. , 20th edition. Blackwell Science Ltd., Oxford, pp. 249–265.

Brodt, S., Klonsky, K., Tourte, L., 2006. Farmer goals and management styles: implications for advancing biologically based agriculture. Agric. Syst. 89, 90–105.

Caballero, R., 2001. Policy schemes and targeted technologies in an extensive cereal-sheep farming system. Agric. Hum. Values 19, 63–74.

Caballero, R., Riseth, J.Å., Labba, N., Tyran, E., Musial, W., Molik, E., Boltshauser, A., Hofstetter, P., Gueydon, A., Roeder, N., Hoffmann, H., Moreira, M.B., Coelho, I.S., Brito, O., Gil, Á., 2007. Comparative typol-

ogy in six European low-intensity systems of grassland management. Adv. Agron. 96, 351–420.
Caskie, P., Davis, J., Wallace, M., 2001. Targeting disadvantage in agriculture. J. Rural Stud. 17, 471–479.
Cooper, R.A., 2003. Sheep and goats. In: Soffe, R.J. (Ed.), Primrose McConnell's The Agricultural Notebook. , 20th edition. Blackwell Science Ltd., Oxford, pp. 500–521.
Defra Agricultural Change and Environment Observatory, 2009. The Farm Practices Survey 2009—Upland and Other Less Favoured Areas (LFAs) report. Defra, York.
Dewar-Durie, A., 2000. The Scottish Sheep Industry: A Way Forward. Scottish Executive, Edinburgh, website publication. http://www.scotland.gov.uk/Publications/2007/06/06110400/0 (accessed 10.05.2010).
Dillman, D.A., 1978. Mail and Telephone Surveys. The Total Design Method. Wiley Interscience, New York.
Dinsdale, D.H., 1950. Hill sheep farming. Proc. Agric. Econ. Soc. 8 (4), 272–295.
Eadie, J., 1971. Hill pastoral resources and sheep production. Proc. Nutr. Soc. 30 (3), 204–210.
Fairweather, J.R., Keating, N.C., 1994. Goals and management styles of New Zealand farmers. Agric. Syst. 44, 181–200.
Fowler, F.J., 2002. Survey Research Methods. Applied Research Methods Series, vol. 1., 3rd edition Sage Publications, Thousands Oaks/London.
Franks, J., 2006. Farming futures: some impacts of the Fischler reforms on livestock farming in the North East of England. J. Farm Manag. 12, 627–642.
Frame, J., Tiley, G.E.D., Waterhouse, A., 2003. Developments in forage systems in the Scottish hills and uplands. In: Kirilov, A., Todorov, N., Katerov, I. (Eds.), Optimal forage systems for animal production and the environment. Proceedings of the 12th Symposium of the European Grassland Federation, Pleven, Bulgaria, 26–28 May 2003. Bulgarian Association for Grassland and Forage Production (BAGFP), Pleven, Bulgaria, pp. 33–36.
Gaspar, P., Escribano, M., Mesías, F.J., Rodrigues de Ledesma, A., Pulido, F., 2008. Sheep farms in the Spanish rangelands (dehesas): typologies according to livestock management and economic indicators. Small Rumin. Res. 74, 52–63.
Gasson, R., 1998. Educational qualifications of UK farmers: a review. J. Rural Stud. 14, 487–498.
Gelan, A., Schwarz, G., 2008. The effect of single farm payments on less favoured areas agriculture in Scotland: a CGE analysis. Agric. Food Sci. 17, 3–17.
Girard, N., Duru, M., Hazard, L., Magda, D., 2008. Categorising farming practices to design sustainable land-use management in mountain areas. Agron. Sust. Dev. 28, 333–343.
Gorton, M., Douarin, E., Davidova, S., Latruffe, L., 2008. Attitudes to agricultural policy and farming futures in the context of the 2003 CAP reform: a comparison of farmers in selected established and new Member States. J. Rural Stud. 24, 322–336.
Gray, J., 2000. The common agricultural policy and the re-invention of the rural in the European Community. Sociol. Ruralis 40 (1), 30–52.
IEEP, Veenecology, 2004. Land abandonment—causes, extent and impact. In: Land Abandonment and Biodiversity in Relation of the 1st and 2nd Pillars of the EU's Common Agricultural Policy; Outcome of an International Seminar in Sigulda, Latvia, 7–8 October 2004. 68 pp.
Köbrich, C., Rehman, T., Khan, M., 2003. Typification of farming systems for constructing representative farm models: two illustrations of the application of multi-variate analyses in Chile and Pakistan. Agric. Syst. 76, 141–157.
MacDonald, D., Crabtree, J.R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., Gutierrez Lazpita, J., Gibon, A., 2000. Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. J. Environ. Manag. 59, 47–69.
McNicol, J., Hirst, D., 2004. Graphical Methods for Multivariate Data. Biomathematics & Statistics Scotland, Edinburgh.
Met Office, 2011. UK Regional Climate: Eastern Scotland, Northern Scotland, Western Scotland. http://www.metoffice.gov.uk/climate/uk/regional/ (accessed 24.05.2011).
Milán, M.J., Arnalte, E., Caja, G., 2003. Economic profitability and typology of Riposella breed sheep farms in Spain. Small Rumin. Res. 49, 97–105.
Milán, M.J., Bartolomé, J., Quintanilla, R., García-Cachán, M.D., Espejo, M., Herráiz, P.L., Sánchez-Recio, J.M., Piedrafita, J., 2006. Structural characterisation and typology of beef cattle farms of Spanish wooded rangelands (dehesas). Livest. Sci. 99, 197–209.
Moravec, J., Zemeckis, R., 2007. Cross-compliance and land abandonment. Deliverable D17 of the CC Network Project, SSPE-CT-2005-022727.
Morgan-Davies, C., Waterhouse, A., Pollock, M.L., Smyth, K., 2006. Local area farming plans—a common reality for farmers and conservationists in the Scottish highlands. Scott. Geogr. J. 121, 385–400.
OECD, 2002. Less Favoured Areas (LFA). Glossary of Statistical Terms. http://stats.oecd.org/glossary/index.htm (accessed 6.10.09).
Oglethorpe, D.R., 2005. Livestock production post CAP reform: implications for the environment. Anim. Sci. 81, 189–192.
Olaizola, A.M., Chertouh, T., Manrique, E., 2008. Adoption of a new feeding technology in Mediterranean sheep farming systems: implications and economic evaluation. Small Rumin. Res. 79, 137–145.
Pack, B., 2010. Inquiry into Future Support for Agriculture in Scotland—The Interim Report. The Scottish Government, Edinburgh.
Riedel, J.L., Casasús, I., Bernués, A., 2007. Sheep farming intensification and utilization of natural resources in a Mediterranean pastoral agro-ecosystem. Livest. Sci. 111, 153–163.
Royal Society of Edinburgh, 2008. Committee of Enquiry into the Future of Scotland's Hills and Islands. Report. Royal Society of Edinburgh, Edinburgh.
Scottish Executive, 2002a. Economic Report on Scottish Agriculture: 2002 Edition. Scottish Executive, Edinburgh.
Scottish Executive, 2002b. Scottish Agricultural Census Summary Sheets by Geographic Area: June 2001. Scottish Executive, Edinburgh.
Scottish Executive, 2003a. Reform of the Common Agricultural Policy. A Summary of the Agreement. Scottish Executive, Edinburgh.
Scottish Executive, 2003b. CAP Reform: Opportunities for Scotland. Consultation Paper. Scottish Executive, Edinburgh.
Scottish Executive, 2004a. Economic Report on Scottish Agriculture: 2004 Edition. Scottish Executive, Edinburgh.
Scottish Executive, 2004b. Scottish Agricultural Census Summary Sheets by Geographic Area: June 2003. Scottish Executive, Edinburgh.
Scottish Executive, 2006a. Economic Report on Scottish Agriculture: 2006 Edition. Scottish Executive, Edinburgh.
Scottish Executive, 2006b. Scottish Agricultural Census Summary Sheets by Geographic Area: June 2005. Scottish Executive, Edinburgh.
Scottish Government, 2008. Scottish Agricultural Census Summary Sheets by Geographic Area: June 2007. Scottish Government, Edinburgh.
Scottish Government, 2009. Rural Scotland Key Facts 2009, A National Statistics Publication for Scotland. Scottish Government, Edinburgh.
Scottish Government, 2010. Scotland Rural Development Programme 2007–2013: Rural Development Regulation (EC) No. 1698-2005. Web only publication. http://www.scotland.gov.uk/Publications/2010/05/05134234/0 (accessed 23.06.2011).
Scottish Government RERAD, 2008. Economic Report on Scottish Agriculture, 2008 Edition. Scottish Government, Edinburgh.
Scottish Government RERAD, 2010. Economic Report on Scottish Agriculture, 2010 Edition. Scottish Government, Edinburgh.
Stott, A.W., Milne, C.E., Goddard, P., Waterhouse, A., 2005. Effect of alternative management strategies on profit and animal welfare in extensive sheep production systems in Great Britain. Livest. Prod. Sci. 97, 161–171.
Stott, A.W., Vosough Ahmadi, B., Milne, C.E., Morgan-Davies, C., Dwyer, C., Kupiec-Tehan, B., Ringrose, S., Phillips, K., Waterhouse, A., 2010. Predicted effects of CAP reform on management of Great Britain's extensive sheep farms. In: Proceedings of the 84th Annual Conference of the Agricultural Economics Society, Edinburgh, 29th–31st March 2010.
Strijker, D., 2005. Marginal lands in Europe—causes of decline. Basic Appl. Ecol. 6, 99–106.
Symon, J.A., 1959. Scottish Farming, Past and Present. Oliver and Boyd Ltd., Edinburgh.
Teagasc, 2003. An Analysis of the Effects of Decoupling of Direct Payments from Production in the Beef, Sheep and Cereal Sectors. Teagasc, Dublin.
VSN International Ltd., 2005. GenStat for Windows, 8th edition. Lawes Agricultural Trust, Hemel Hempstead.
Willock, J., Deary, I.J., Edwards-Jones, G., Gibson, G.J., McGregor, M.J., Sutherland, A., Dent, J.B., Morgan, O., Grieve, R., 1999. The role of attitudes and objectives in farmer decision making: business and environmentally-orientated behaviour in Scotland. J. Agric. Econ. 50, 286–303.

BIBLIOGRAPHY

Bernués, A., Riedel, J.L., Asensio, M.A., Blanco, M., Sanz, A., Revilla, R., Casasús, I. 2005. An integrated approach to studying the role of grazing livestock systems in the conservation of rangelands in a protected natural park (Sierra de Guara, Spain). Livestock Production Science, 96. 75–85.

Castel, J.M., Mena, Y., Delgado-Pertíñez, M., Camúñezb. J., Basulto, J., Caravaca, F., Guzmán-Guerrero, J.L., Alcalde, M.J. (2003) Characterization of semi-extensive goat production systems in Southern Spain. Small Ruminant Research, 47. 133-143.

Forestry Commission (2010) Archived grants and licences news items: Funding limit relaxed to speed up tree planting (published 12th February 2010). http://www.forestry.gov.uk/forestry/INFD-836E5U *(accessed 01/02/2013*).

Gafsi, M., Legagneux, B., Nguyen, G., Robin, P. (2006) Towards sustainable farming systems: effectiveness and deficiency of the French procedure of sustainable agriculture. Agricultural Systems, 90. 226-242.

Gaspar, P., Escribano, A.J., Mesías, F.J., Escribano, M., Pulido, F. (2011) Goat systems of Villuercas-Ibores area in SW Spain: problems and perspectives of traditional farming systems. Small Ruminant Research, 97. 1-11.

Gaspar, P., Mesías, F.J., Escribano, M., Rodrigues de Ledesma, A., Pulido, F. (2007) Economic and management characterization of dehesa farms: implications for their sustainability. Agroforestry Systems, 71. 151-162.

Holland, J.P. (2001) Plant herbivore interactions within a complex mosaic of grassland, mire and montane communities. PhD Thesis, University of Glasgow.

MAFF (1975) Energy Allowances and Feeding Systems for Ruminants. Technical Bulletin No. 33 . London: Her Majesty's stationary office. 79p.

MLURI (1997) Hill Grazing Management Model, Hill Grazing Management Model, Ecological Manual, for Windows version 1.0.

Morgan-Davies, C., Waterhouse, A., Pollock, M.L., Milner J.M. (2008) Body condition score as an indicator of ewe survival under extensive conditions. Animal Welfare, 17, 71-77.

Petit, M., Agabriel, J., D'Hour, P., Garel, J.P. (1994) Quelques caractéristiques des races bovines allaitantes de type rustique. INRA Productions Animales, 7. 235-243.

Quetier, F., Marty, P., Lepart, J. (2005) Farmers' management strategies and land use in an agropastoral landscape: Roquefort cheese production rules as a driver of change. Agricultural Systems, 84. 171-193

Ruiz, F.A., Mena, Y., Castel, J.M., Guinamard, C., Bossis, N., Caramelle-Holtz, E., Contu, M., Sitzia, M., Fois, N. (2009) Dairy goat grazing systems in Mediterranean regions: A comparative analysis in Spain, France and Italy. Small Ruminant Research, 85. 42-49.

SAC (2002) The Farm Management Handbook 2002/2003. 23rd Edition. Edinburgh: SAC. 528 p.

SCA (1990) Feeding Standards for Australian Livestock. Ruminants. Standing Committee on Agriculture and CSIRO, Melbourne, 266 pp.

Scottish Government (2012) Consultations. http://www.scotland.gov.uk/Consultations/ (*accessed 17/03/2012*).

Somerville, S.H., Lowman, B.G., Edwards, R.A., Jolly, G. (1983) A study of the relationship between plane of nutrition during lactation and certain production characteristics in autumn-calving suckler cows. Animal Production, 37. 353-363.